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AN ANALYSIS OF THE POTENTIALS AND PROSPECTS OF INCREASING EDIBLE OIL PRODUCTION IN WEST PAKISTAN

Foreign Economic Development Service
U.S. Department of Agriculture
cooperating with
U.S. Agency for International Development

ABSTRACT

This study, done by the U.S. Department of Agriculture in cooperation with the U.S. Agency for International Development, assimilates information from U.S. resources on the research, production potentials, and problems of oilseed production and processing in the United States, Pakistan, and other countries where relevant. It includes a general economic analysis as well as detailed discussions on the production of safflower, sesame, peanuts, soybeans, sunflowers and cottonseed. Increased yields may be of major importance in increasing oilseed production in Pakistan since fierce competition for land and water by summer crops may eliminate, or at least jeopardize, additional acreage as a feasible option. Also, only safflower and perhaps sunflower are tolerant to the winter season. Many crucial information gaps exist, however, especially in the areas of oil content; potential yields for Pakistan; insect and disease problems in Pakistan; and soil, water, and climate factors and their effects on the plants.

KEY WORDS: Oilseeds, Edible Oils, Pakistan, Safflower, Sunflower, Sesame, Peanuts, Soybeans, Cottonseed.

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SUMMARY AND ASSESSMENT

BACKGROUND

This draft report constitutes the first phase of a proposed two-phase study on the potential for increasing oilseed production in West Pakistan. It was prepared by the U.S. Department of Agriculture under the auspices of the Bureau for Near East and South Asia, Agency for International Development. Sections were written on a subject matter basis with the authors, where applicable, generally following an outline which was agreed upon by AID and USDA.

The purpose of this phase was to assimilate information from available U. S. resources on the research, production potentials, and problems of oilseed production and processing in the United States, Pakistan, and other countries where relevant.

OBSERVATIONS

This paper constitutes a review of the economic and agronomic reports on the various oilseed crops and a synthesis of subsequent discussions. The following tabular summary of factors highlighted in the Phase I report represents an effort to present the material in such a way as to facilitate comparative analysis. Although the intent of this supplement is not to promote or eliminate any particular crop from consideration, there seem to be a number of valid observations that can be made:

1) The only Rabi (winter) crop among the six (excluding rape & mustard) is safflower, though sunflower may have sufficient seasonal tolerance.

2) Fierce competition for land and water by Kharif (summer) crops may eliminate, or at least jeopardize, additional acreage as a feasible option.

3) Where reliable data on current Pakistani yields exist, a great potential is indicated with increased yields alone.

4) Good water control is consistently a necessary requirement for good production.

5) The demand for cotton fiber, separate from seed, must be evaluated as a factor in crop competition.

6) More information is needed with respect to specific crop rotations by region to thoroughly evaluate crop competition.

7) Large information gaps remain on specific commercial production and marketing data for Pakistan: insects and diseases; soil and water; growing season; micro-climate, i.e., north versus south; processing plants; yields; use and market for by-products; and cultural-consumer acceptance. Though general information is available, there is a need for more precise data; e.g., consumptive-use figures with regard to water requirements.

8) Any summer crop competes with the following crops, which all followed an increasing acreage trend from 1960-68:

Crop	Acres
Rice	3,500,000
Cotton	4,400,000
Millet	2,200,000
Maize	1,500,000
Sorghum	1,400,000

9) Any winter crop competes with the following crops:

Crop	Acres
Wheat	14,700,000
Gram	2,800,000
Rape & Mustard	1,300,000

For the 1960-61 through 1967-68 crop years, only gram did not follow an increasing trend in acreage. Gram acreage held basically static.

Table 1.--Tabular summary of production and processing factors by crop.

Factors	Crops: Safflower	Sesame	Peanuts	Soybeans	Sunflower	Cottonseed	Rape & Mustard
YIELD 1/	Projected for Pakistan: 2/3 that of wheat; 4500 Kg/ha. is possible. U. S.: Calif. & Ariz. (Irrig). 2400 Kg/ha. (average) Plains States (dryland), 2000 Kg/ha.	Pakistan: 2/ 280 Kg/ha. More research needed. U. S.: less than 1000 Kg/ha.	Pakistan: 2/ 1280 Kg/ha. Second to Safflower. U.S.: 2300 Kg/ha.	Pakistan: 6/ 1100-2000 Kg/ha. Max. 3300 Kg/ha. U. S.: 2150 Kg/ha. in Midwest 1750 Kh/ha. in South 3400 Kg/ha. consistently for good farmers.	Average world-wide of improved varieties: 1700 Kg/ha. U.S.: - 1966: Average from 13 varieties for 13 locations was 1520 Kg/ha. Maximum for Pakistan: 2800 Kg/ha. on trial basis.	Pakistan: 575 Kg/ha. 2/ U.S.: 7/ 2700 Kg/ha.	Pakistan: 460 Kg/ha. 2/
PROCESSING FACTORS & BY-PRODUCTS 3/	30-40% oil, 65% cake & meal latter with 40% Protein. New varieties may increase oil content. High oleic type available. Oil dark w/straw odor. Meal requires treatment for bitterness & laxative effect. Uses of meal: cattle feed and also for swine & poultry w/re-fining (decortication).	40-60% oil, 45% cake & meal, latter w/42% protein. Oil is highly stable. High protein forage (leaves 20-29%, stems 4-11%). Market may exist for whole seed.	30% oil & 43% cake & meal at 45% protein. Dryness at harvest not uniform, 30-70%. Oil must be deodorized for ghee-no special processing for human food. By-Products: Human food, with or without processing. Livestock & poultry feed.	Unstable oil. Can store bean in open; 18% oil and 79% cake & meal at 42% protein. Constant supply to justify heavy capitol investment. By-Products: Industrial uses. Livestock feed and potential human food.	Special drying equip-ment. 35% oil, 42% cake and meal, latter contains 41% protein. Meal has low fiber. Oil very stable. By-Products: Industrial uses, e.g. potato chips, livestock feed & human food.	20% oil, 46% cake & meal, latter with 36% protein. Must deodorize & bleach oil to bind gossypol. Oil stability high. By-Products: Animal feed & soil amendment; soap; human food; cotton fiber. Meal is, by far, most important.	Oil not used for ghee. Rape contains 40% oil and Mustard contains 23% oil. No percentages available for meal but assume 10% loss. Percents protein in cake & meal are 35% & 32%, respectively, for rape & mustard.
PRODUCTION CONSTRAINTS	Seedlings not agressive; thus, weeds & volunteer crops can be problem during seedling stage (2 wks. to 3 mos.) Lack of moisture at flowering will result in few filled seeds.	20 C minimum for germination. Shatters easily but new varieties resist shattering. Seed must be treated. Little research to date. Moisture of seed can not exceed 10% in storage w/o loss of viability.	Problem w/aflotoxins. Soil & temp. critical factors. Soil depletors. Sensitive to frost.	Lodging, shattering, boron toxicity, photo-sensitive, diseases & weeds. Weeds are major hazard. PL-480 imports.	Photo periodism is a factor but data lacking-much research needed.	Insect problem. Improvement in under-standing of proper water requirements-improved extension.	Fits nicely into a rotation.
INSECTS & DISEASES	Root rot & safflower fly, latter carried by pohli. Disease common w/high humidity. Birds major problem.	Root rot, bacterial blight, alternaria blight. Aphids & sesame leaf rollers.	Inadequate information re Pakistan: leaf spot is world-wide problem, but other diseases & insects vary from country to country.	Thirty insects attack in North India. Fungus & root rot; Virus yellows severe in India.	Susceptibility affected by day length & light intensity. Rust, downy mildew, wilt. Head moth & broom rape potential problems. However, lack of information in W. Pakistan. Survey & research needed.	Boll rots following insect damage. Insects probably most serious problem; Pakistani researchers feel the Leaf hopper is most serious in Pakistan. Seedling diseases cor-related with low temp. & high moisture during germination.	
GROWING SEASON 4/	Winter crop. Oct. - Mar. 120 days min; usually 150 days.	Summer crop. 70-120 days. Five frost-free months.	Summer Crop. 190-200 days- Plant Feb. 15 to June 1, dig Sept. 1 thru Dec.	Summer Crop. 140 days- Plant early as April in North & late as July in South. Photo-sensitive, needs 14.5 hour day.	Summer crop. 100-150 days. Wide tolerance for possible early spring planting.	Summer crop. 150-200 days, latter for max.yields. Plant April-June (early preferred to avoid high temp. during fruiting).	Winter crop.

Factors	Crops						
	Safflower	Sesame	Peanuts	Soybeans	Sunflower	Cottonseed	Rape & Mustard
WATER REQUIREMENTS	Water control critical. Consumptive use: 75-110 cm for max. yields.[5] Deep root zone dictates replenishing moisture if crop to follow in rotation. Good moisture prior to planting.	Drought resistant. Will not tolerate excessive soil moisture. Consumptive use: 50 cm for best performance.	Irrigation required. Drought resistant but shortage of moisture when setting pods reduces yield. Consumptive use: 50-55 cm.	Irrigation is necessary. Is sensitive to moisture stress during flowering. Consumptive use: 50-80 cm.	Peshawar possibly drying, Irrig. recommended. Moisture for rapid germination critical. Consumptive use: 45-62 cm.	Irrigation necessary. High consumptive use: 50-125 cm.[7] Plant tolerant to water quality.	
CROP COMPETITION [4]	Primarily wheat but also mustard & rape. Can utilize same equipment as wheat. Doubtful cotton can be included in rotation (suscept. to same disease)	Cotton, rice, peanuts. Fits well into a rotation (versatility of maturity groups & planting dates).	Maize, Millet, Sorghum, Cotton, Rice.	Same as peanuts.	Cotton Rice Maize Millet Sorghum	Rice Sugar Cane	Wheat
SOIL REQUIREMENTS	Well drained & near neutral. Clay soil is a problem.	Well drained. Sensitive to salinity. Little response to fertilizer.	Will not tolerate poor drainage. Friable soil, primarily for harvesting. Sensitive to salinity (if leached must be full root zone).	Wide range but best deep & well drained. Varieties vary in tolerance of salinity. Responds to fertilizer well.	Well drained - about same as corn or cotton. Responds to fertilizer. Not sure on salinity but suspect tolerant. Research recommended.	Well drained; loam to sandy loam. High salinity tolerance (more tolerant than soybeans but less than rape).	
CLIMATIC FACTORS [4]	24°-32°C up to flowering & immediately thereafter for max. yields. High temp. & dry best during seed develop, maturity & harvest. Will tolerate temp. above 38°C, w/moisture, but upper limit not determined. Will tolerate temp. -7°C in seedling stage. Adversely affected by high humidity (diseases); rain at harvest will germinate seed in head.	Dry conditions - humidity increases disease problem. Fruiting slow over 40°C but will tolerate 50°C w/good moisture. Performs best where temp. remains high entire growing season.	High temp. day & night. Low temp. will bring growth to stop. Day temp. of 26°-32°C, and night temp. of 16°-21°C, for good production.	Photo-period sensitive. Will grow at temps. from 21°-38°C. Threshold temp. for germ is 10 C. Moisture stress potential at high temp.	Sensitive to extremes of temp. but seedlings tolerate frost. Temps. above 32°C questionable.	Tolerates high temp. but successful fruiting very low above 45°C. Chilling sensitive plant - plant injury at temp. below 15°C. Optimum growth at day temp. of 32°-34°C & night temp. of 21°-27°C.	
PLANTING TRENDS	Minor crop in Pakistan - India has largest acreages.	32,000 ha. Subsistence crop. Acreage increasing.	65,000 ha. 1968-69. 70% in northern part of country. Acreage increasing.	Large imports. Oil is well accepted for ghee. No information on acreage.	Not grown commercially. 3000 acres (1970).	1.76 million ha. in 67-68 season. Acreage increasing.	Third among Rabi crops, behind wheat & gram. 5.36 thousand ha. Acreage increasing.

1/There is considerable variation in judgement as to potential yields for Pakistan. U. S. yields cited are averages but the spread between maximum and minimum is great.

2/Five year average, crop years 1960-61 through 1964-65. Actual commercial yields for safflower, soybeans & sunflower not available.

3/There is considerable variation between reports in statistics regarding percentages of oil and cake and meal. Also, they vary according to many climatic, agronomic and variety factors.

4/These factors should be evaluated in a regional context due to variations between regions, primarily North and South.

5/Wide variation dictated by climate & soil.

6/Based on cultural studies carried out in various areas of Pakistan. Those cited are for Hyderabad region.

7/Essentially all cotton in Pakistan is irrigated while most cotton in U. S. is not.

ASSESSMENT - STRATEGY

It was anticipated that, as this phase neared completion, gaps in necessary information would become evident and a second phase might then be implemented to complete the study in Pakistan. A review of the report and subsequent discussions indicate clearly that crucial information gaps do exist. Also, there was a divergence of opinion among reports on several topics; e.g., oil content, potential yields for Pakistan, and insect and disease problems. Therefore, Phase II is definitely necessary if valid conclusions are to be drawn.

The following appear to be the major areas for further evaluation and study:

1) Each region should be assessed in terms of the following, as they pertain to each crop:

   a) Climate - temperature, elevation, humidity, rainfall (distribution), etc.

   b) Soil - type, depth, friability, drainage, salinity, etc.

   c) Land availability and use.) Toward the larger
) question: why is
   d) Water availability and use.) land idle?

   e) Possible specific crop rotations.

2) Comparative processing data is needed:

   a) Physical plant - capital.

   b) New technology.

   c) Supply of raw material - consistency.

3) Identify coefficients and use of by-products - current and potential.

4) Evaluation of economic factors, such as:

   a) Comparative advantage between oilseed crops.

   b) Pricing policy - import substitute policy.

   c) Marketing of oil and by-products.

   d) Production cost information.

5) There are indications some steps in processing, as with peanut oil for example, will require the introduction of new technology and capital.

6) Like information must be secured on rape and mustard seed production in view of two obvious factors: (1) they are Rabi crops, thus are potentially subject to less competition from established crops and (2) they are presently third in acreage among Rabi crops, behind wheat and gram.

7) There is a variation among reports as to oil, cake, and meal percentages for each crop. It is not clear, for example, whether percent of oil in safflower is computed before or after decortication.

8) Assess the comparative extension requirements.

9) Identify and evaluate cultural inhibitors.

ECONOMIC ANALYSIS

ECONOMIC ANALYSIS 1/

This analysis is prepared within the framework of an outline on oilseed crop possibilities in West Pakistan which was developed by U.S. Department of Agriculture in response to a request from U.S. Agency for International Development. The general plan is for the analysis to be completed in the United States, to the extent that data will allow. A subsequent study in West Pakistan is contemplated which will extend the analysis and make it more definitive.

The analysis has two broad aspects, namely, agronomic and economic. The Agricultural Research Service has assumed responsibility for the agronomic presentation and the Economic Research Service for the economic analysis. After rather extensive investigation of the data at hand, ERS representatives believe that ERS can best contribute by providing (1) some discussion of "Agronomic and Economic Interactions" and (2) preparing the analysis of "Supply and Demand of Oilseeds and Oilseed Products."

AGRONOMIC AND ECONOMIC INTERACTIONS

OTHER CROPS

There are two management aspects to the introduction or increase in acreages of oilseed crops as they either compete with or complement crops already in rotation in a country such as West Pakistan. One is the year-round utilization of land on an optimum physical production basis. The limiting production factors, such as water and soil fertility, must, of course, be considered.

The other broad aspect is that of economic returns. From a farm management point of view, it is maximum net returns per farm, but from a national policy point of view, it could be gross returns per acre. Since more than one crop can be grown on the same land in the course of a year, the criterion is one of total returns for the year rather than returns per crop.

In the Rabi (winter) season in West Pakistan, oilseed crops must compete with wheat, gram, and barley. Rape and mustard seed

1/ Frederic A. Coffey, Agricultural Economist, Foreign Programs Group, Foreign Development and Trade Division, Economic Research Service, U.S. Department of Agriculture, prepared this discussion on economic analysis.

together already rate next to wheat in terms of acres planted in the Rabi season. Some production of linseed in that season also should be noted. In some parts of West Pakistan, some rice and jowar (sorghum) can be grown as Rabi crops. While sunflowers are not grown commercially at present, their climatic tolerance would allow early spring seeding if moisture is available.

In the Kharif (summer) season, crops competing for land use include rice, cotton, chick-peas, millet, sugarcane, maize, sorghum, peanuts, and sesame. While sugarcane is essentially a warm season crop, it competes for land the year round. Of the Kharif crops, rice and sorghum appear to have best potentials as all season crops in some areas.

Currently safflower seed and soybeans, oil crops not now produced in West Pakistan but which appear to have considerable potential, are classified as Kharif crops. Sunflower seed, as noted above, has considerable seasonal tolerance.

The length of the growing season -- from planting to harvest -- for the different crops requires study for developing optimum land utilization patterns. Involved are crop rotations. For example, early planted cotton in India has a growing season of 6 to 7 months. If planted in May and harvest is over in December, it would probably be too late for wheat. Rapeseed as a zaid (late) Rabi crop could be planted in early January and harvested in May, about 4 months later. Soybeans or groundnuts could follow and be harvested in September. There would be ample time for seeding wheat, which could be followed by early cotton; then a repeat of the rotation would be possible.

Official Government of Pakistan (GOP) agricultural statistics indicate that about 11 to 14 million acres in West Pakistan have been annually in "current" fallow (Table 2). Moreover, only about 12 to 15 percent of the cropped land has been "sown more than once" during the year (Table 2). These data suggest the availability of a considerable acreage which might be used in complementarity for producing oil crops, provided moisture and soil conditions as well as crop rotations will permit.

The question of the approximate additional acreage of oil crops needed in West Pakistan to produce enough oil to offset annual average imports will be discussed more fully later.

A recent Agricultural Attache's report quotes an oil industry representative as saying that 700,000 acres of sunflower seed production would produce enough edible oil to eliminate the need for oil imports.2/ Without being definitive, this gives some idea of

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2/ Pakistan: Fats and Oils Annual Report. Apr. 17, 1970. PK-0024 Foreign Agricultural Service, USDA. Communication from Rawalpindi to Washington. Enclosure No. 1 quotes an article from the Pakistan Times on "Sunflower to be Cultivated in Sind, Punjab."

Table 2.--Land utilization in East and West Pakistan, including fallow and acreage sown more than once, same year, selected years.

Year and area unit	Total area cultivated (1)	Net area sown (2)	Current fallow (3)	Percent in fallow 3 ÷ 1 (4)	Total cropped area (5)	Area sown more than once (6)	Percent cropped area sown more than once (7)
	Million Acres			Percent	Million Acres		Percent
1949-50							
East Pakistan	22.33	20.09	2.23	10.0	25.66	5.56	27.7
West Pakistan	37.04	28.08	8.96	24.2	N.A.	N.A.	---
1954-55							
East Pakistan	22.12	20.96	1.16	5.2	27.53	6.57	31.3
West Pakistan	37.85	29.29	8.56	22.6	32.80	3.50	11.9
1959-60							
East Pakistan	21.66	20.58	1.08	9.6	25.48	5.90	28.7
West Pakistan	40.84	32.30	7.54	18.5	35.40	3.11	9.6
1964-65							
East Pakistan	22.04	21.10	0.94	4.3	28.54	7.43	35.2
West Pakistan	46.32	35.00	11.32	24.4	40.14	5.14	14.7
1965-66							
East Pakistan	22.33	21.60	0.73	3.3	29.54	7.94	36.8
West Pakistan	47.60	34.44	13.16	27.6	38.66	4.22	12.3
1966-67							
East Pakistan	22.43	21.11	1.32	5.9	29.04	7.93	37.6
West Pakistan	48.66	35.18	13.47	27.7	39.30	4.11	11.7

Source: Yearbook of Agricultural Statistics 1968. Fact Series No. VII, Jan. 1969. Food and Agriculture Division. Ministry of Agriculture and Works, Government of Pakistan. Rawalpindi.

the magnitude of the oil crop acreage needed. As to sunflower seed production, the article assumes it can follow cotton as a Rabi crop. If feasible, and since cotton is not often followed by a Rabi crop, sunflower production could be considered in this context a complementary crop.

OTHER USES FOR WATER

This is first an agronomic problem in that the agronomist specifies what crops can be grown seasonally or annually. A major consideration is, of course, the availability of moisture. Within this framework, relative economic returns play an important role. Oilseed crops may be competitive, and not merely complementary, for land and water use, depending on relative net returns per acre. However, it is suggested that a new oil crop would have to show a substantially higher net per acre return, possibly 50 percent or more than the returns for crops already competing, before acreage and water use shifts would become significant.

Preliminary studies indicate that utilization of water and land in the Kharif season in West Pakistan is highly competitive. Detailed economic analysis of relative costs and returns of all competing crops appears essential in determining the potentials of oil crops to compete for water and land. Numerous deterring factors, other than economic, suggest any wholesale shift to oil crops in the Kharif season would not be a reasonable expectation.

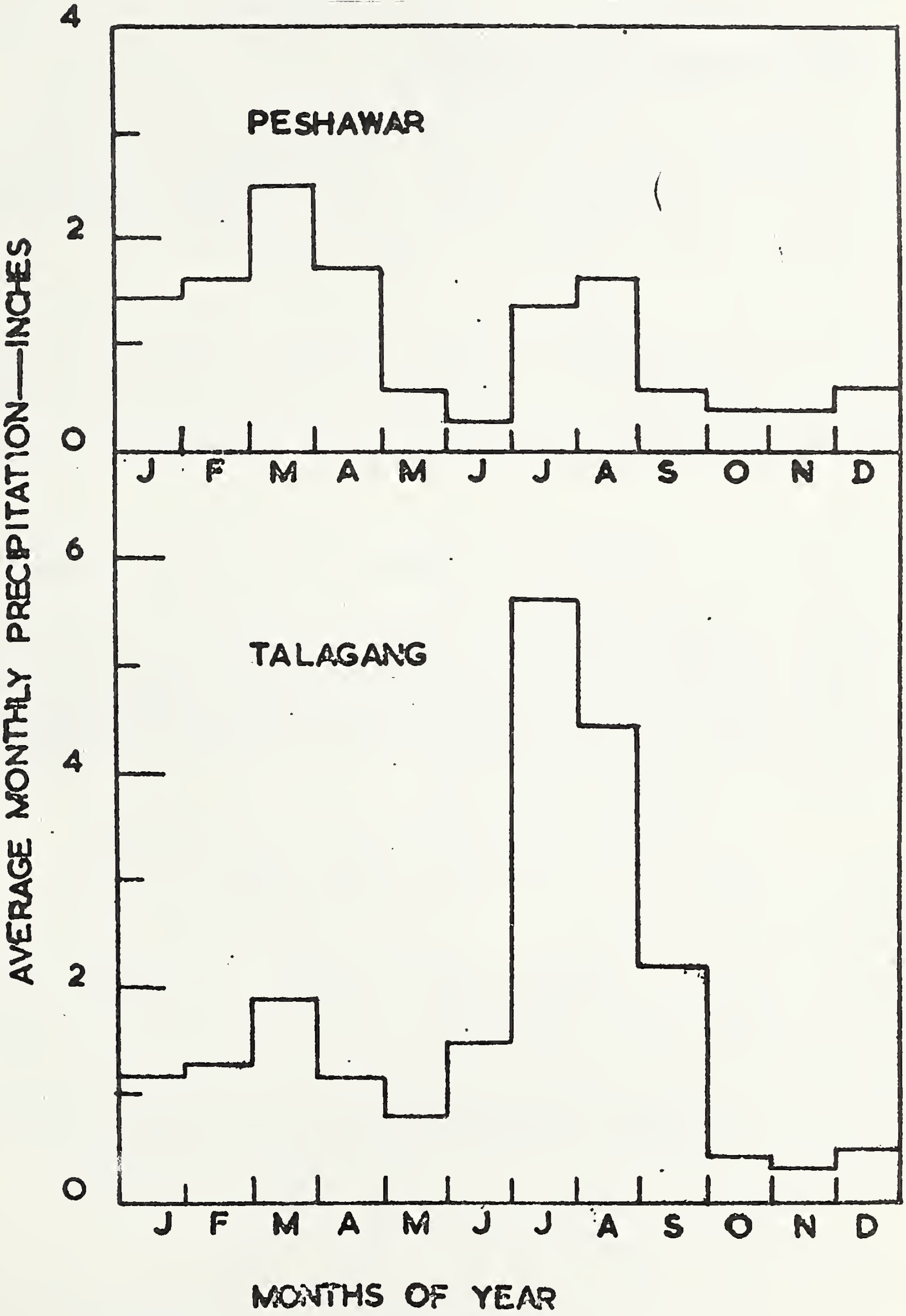
Oil crop competition for water may be more successful in special situations. One would be where irrigation water is limited and an oil crop had relatively lower water requirements. In sandy soils, peanuts may prove very competitive where sprinkler irrigation is feasible.

A shift in water use from a small percent of subsistence crops to oil crops looks promising when net per acre returns are substantially favorable to the later. Another percentage possibility which merits study is use of water and otherwise fallow land in the Kharif season to produce oil crops.

In the Rabi season, moisture from rains and irrigation sources used to produce wheat is not likely to be available for other crops -- as long as the national pricing policy remains so favorable for wheat. However, some Kharif crops are harvested too late for October to December planting of wheat. Thus, there is a possibility of some oil crops competing as late Rabi crops for water and land. One source indicates that sunflowers could follow " . . . cotton on irrigated land where, in the past, no crop has been grown." 3/ Since there are other Kharif crops

3/ Ibid. See p. 2 of the Attache's report.

Figure 1.-- Illustration of variation in monthly precipitation, 1931-1960.



with long growing seasons, as well as late Kharif crops, the feasibility of oil crops following, to use whatever moisture is available instead of leaving the land to Rabi fallow, needs checking.

OTHER USES OF LABOR OR MACHINERY

No substantial body of pertinent data is available in the United States for West Pakistan. Moreover, such an analysis would be more useful once an oil crop package program has been developed on a preliminary basis. Then competition of specific crops for labor and machinery could be analyzed in terms of timing and location as well as total needs.

Utilization of what would otherwise be fallow land for production of oil crops leads to the general observation that the size of the farm operation would be increased. Thus total use of labor and machinery for the year would increase. However, it would be dangerous to presuppose that an addition to the labor force and more machinery would be needed on the individual farm.

COST OF PRODUCTION, RETURN TO FARMER AND TO THE ECONOMY

Cost of production and returns to farmers from different oil crops should be deferred to the second phase of the study when detailed micro-analytic data pertinent to economic research can be made available in West Pakistan. However, preliminary to the economic analysis, it is useful to approximate the percentage of oil, cake, and meal in the different oilseeds and to approximate their relative outputs per acre.

Of the eight oil seed crops under consideration, the percentage of crude oil in the seed ranges from 17 percent for cottonseed to 50 percent for sesame seed (Table 3). On a per ton basis, rape, safflower, and sunflower seed produce more oil than do cottonseed, soybeans, and peanuts. The percentage yield of cake and meal from seed varies from 42 percent for sunflower seed to 79 percent for soybeans. The percent of protein in cake and meal varies from about 22 percent for safflower seed to approximately 45 percent for peanuts. In comparing the amount of protein in the cake and meal produced from a short ton of seed, soybeans lead with 660 pounds, peanuts are second with 384 pounds, and sunflowers are third with 344 pounds.

A practical comparison is that of amounts of oil, cake, meal, and protein each seed crop will produce per acre of land (Table 4). Based on the assumed yields, oil output is highest for safflowers, peanuts, and sunflowers. Cottonseed, mustard, and sesame seed have low per acre outputs of oil.

Table 3.--Percent yield of oil, cake and meal, and protein from selected oil seed crops. 1/

Oilseed crop	Seed yield 2/ Of crude oil	Seed yield 2/ Of cake and meal	Protein yield 2/ In seed	Protein yield 2/ In cake and meal
	- - - - - Percent	- - - - -		
Cottonseed	16.9	46.5	3/ 30	3/ 36
Peanuts 4/	28.7	42.7	25	3/ 45
Sesame seed	50.0	---	25	42
Rapeseed	40.0	---	---	35
Mustard seed	23.0	---	---	5/ 32
Soybeans	18.2	78.6	37	42
Safflower seed	32	65	---	22
Sunflower seed 6/	32	42	---	41
Copra, dried	64	35	---	22
Palm kernel	47	---	9	19
Castor beans	50	46	18	36
Linseed	38	62	24	32

1/ The contents of seeds of an oil crop vary according to many climatic, agronomic, and variety factors. Over time, there has been a tendency for the oil content in seeds to increase. The tabulations here cannot be considered precise for a given country and set conditions. Principal sources were as follows:

(1) Conversion Factors and Weights and Measures for Agricultural Commodities and their Products. Statistical Bulletin No. 362. pp. 20-21, 24-26, and 76. Economic Research Service. U.S. Dept. Agr. June 1965.

(2) Feedstuffs. Yearbook 1970. Table page 87. Miller Publishing Company. Minneapolis, Minn.

(3) Altschul, Aaron M. Processed Plant Protein Foodstuffs. Academic Press Inc. New York. 1958.

(4) Jamieson, George S. Vegetable Fats and Oils. Monogram, Second Edition. Reinhold Publishing Corporation. 1943.

(5) Henry and Morrison, Feeds and Feeding, 18th Edition. The Henry-Morrison Co., Madison, Wisconsin, 1923.

2/ Based on expeller extraction rather than the solvent process. The former is more common in the LDC's.
3/ Without hull or shell. Also delinted in case of cotton.
4/ Farmers stock unless otherwise specified.
5/ For mustard feed or bran.
6/ Percentages based on new Russian varieties.

Table 4.--Comparison of probable oilseed crop output per acre of oil, cake and meal, and protein in the cake and meal, selected crops, West Pakistan.

Oil seed crop	Assumed yield per acre	Output per acre: Oil	Cake and meal: Total	Cake and meal: Protein
	Pounds			
Cottonseed 1/	500	84	232	84
Peanuts 1/	1,275	366	544	245
Sesame seed 1/	245	122	2/ 110	2/ 46
Rapeseed 1/	425	170	3/ 212	3/ 74
Mustard seed 4/	425	98	3/ 285	3/ 91
Soybeans 5/	1,070	195	841	353
Safflower seed 6/	1,500	480	975	214
Sunflower seed 5/	890	285	374	153

1/ West Pakistan produces this crop. Assumed yield is within range of yields for the 1966, 1967, and 1968 harvests.

2/ No reliable estimate is available of cake and meal output from sesame seed. A 45 percent output assumes 5 percent waste.

3/ No cake and meal percent of output from rape and mustard seed is available. In processing both seed crops, a 10 percent waste loss is assumed.

4/ Official crop statistics combine rape and mustard seed. Mustard seed yield assumed to be the same as for rape.

5/ No official yield data are available. If future production is based on seeding of improved varieties, it seems reasonable to assume a yield higher than in most producing countries, but under that for the United States.

6/ Production experience limited. Only reliable yield data found pertains to Arizona and California, under irrigation. Efforts to develop commercial production in Montana, Nebraska, and Texas have failed. California-Arizona seed yields in 1966-69 period ranged from 1850 to 2650 pounds per acre.

Safflowers and soybeans have high potential outputs of cake and meal on a per acre basis. The peanut cake and meal output can also be substantial. Since exports of cake and meal already are important as a source of foreign exchange earnings, these crops may have special importance in future planning.

The proteins in cake and meal, when measured on a per acre output basis, run highest for soybeans, peanuts, and safflowers. As ingredients in cake and meal, such proteins are now largely exported. However, increased production of oil crops, such as the three cited, could provide important supplies of proteins for supplementing human diets and expanding livestock production.

From the point of view of national planning and promotion of increased oil crop production, the analysis would seem to justify two observations. One is that cottonseed production per acre is not likely to produce enough oil, cake, and meal to make it competitive as such. Rather, increased cottonseed production must be justified on the basis of returns for cotton or a combination of cotton and cottonseed.

The other observation is that sesame seed has a low yield and, thus, on a per acre basis, produces relatively small amounts of oil, cake, meal, and proteins. It is an established crop, but is more important in East than West Pakistan. Moreover, it is a subsistence crop in that it is locally consumed. Oil is extracted from only a portion of the seed and processing is done locally in small plants. Except for an agronomic breakthrough, there seems little justification for including sesame in the list of oil crops with expansion potentials.

POTENTIAL PROCESSING ECONOMICS

The term "vegetable oil mills" may be used to cover the entire panorama of processing oilseed crops for consumers in Pakistan. It is difficult to present a clear, accurate picture of the whole process because of limited and fragmented data. Considerable literature is available, but it is limited in value for purposes of economic analysis. Rehashing this literature would serve no useful purpose. It does appear feasible, however, to outline the nature of the vegetable oil mill industry and, in brief fashion, to point out some of the problem areas.

Types of Vegetable Oil Mills

There are three types of oil mills in West Pakistan: (1) the extraction or crushing mills, (2) the oil refineries, and (3) the hydrogenating plants. Extraction mills crush the oilseed to obtain crude oil and oil cake. The oil refineries

process the crude oil to purify the oil, which can then be marketed as salad or cooking oil or used to produce hydrogenated oil products. Refined oil is hydrogenated mainly in West Pakistan to produce vegetable ghee, which is known locally as vanaspati.

Some of the vegetable oil mills perform only one basic processing function. Still others perform two or even all three of the basic functions. In addition, there are other processing steps which are associated with these three types of mills. Some crushing mills, for example, clean, hull or shell or decorticate, and delint before extracting the oil. Deodorizing is an important step in refining certain kinds of oil such as peanut oil.

Interest here focuses on the extraction of oil from oilseeds because the mills performing this function provide the principal market for oilseed crops. However, the successive steps in processing must be considered because of the vulnerability of the industry to consumer preference and demand.

Types of Extraction Mills

The extraction mills in West Pakistan may be divided into three general groups:

1. Kohlus or village mills
2. Expeller plants
3. Solvent plants

The kohlus or village mills are the most common and go back historically to antiquity. Thru use of the pestle and mortar principle, the seed is crushed. Probably about two-thirds of the oil is drained off, but about one-third remains in the residue, which becomes an oil saturated cake which includes hulls and lint (the lint remaining on cottonseed after seed cotton is ginned).

The village mills are very small. Originally they were hand powered. The bullock then came to supply power. Some of the kholus mills have modernized in that steel has replaced some of the pivotal wooden parts and the electric motor has replaced the bullock. Sproull estimates that there are about 1,500 steel kholus mills and about 15,000 village mills which have not modernized. 4/

4/ Edible Oil Industry in Pakistan, John Sproull. USAID/Lahore, Sept. 1970. Typed manuscript.

These mills are simple in design and can be constructed quickly. Little capital is required. They operate to supply local demand for oil. When the oilseed supply is exhausted, they close down. Their operation is largely independent of considerations outside the village, although some of the crude oil is sold to the refineries. They process mostly rapeseed and cottonseed. Even though the oil extraction is very inefficient, the mill has very little overhead and remains competitive.

The expeller plants are more recent in vintage and vary from small to large plants. Sproull compiled a "Glossary of Terms" in which expeller is defined as "a powered device for removing oil from oilseed by constricting its passage through the machine and thus applying pressure, increasing as the process continues." 5/ Estimates of the number of expeller plants vary considerably; Sproull estimated 3,500 of all sizes in West Pakistan with capacity to extract about 250,000 long tons of oil when operating three months per year.

The expeller plants leave considerably less oil in the residue cake than do the kholus and village mills. It is estimated that expeller cake contains from 6 to 12 percent oil on a weight basis compared with about 33 percent in the village mill cake.

Some of the expeller mills have about the same capacity as the village mills. The larger mills are located in the cities. One list of the larger mills indicated that, out of 148, 123 were located in the districts of Lyallpur, Sargodha, Lahore, Multan, Hyderabad, and Karachi.

Considerable extractive capacity is located in the areas producing cottonseed, rape, and mustard seed. (Table 5) A much more precise study of plant locations in relation to oilseed production areas is needed. In general it appears that plants are fairly well located in order to hold down costs of transporting oilseed to mills. The 51 expeller mills in Karachi appear to be an exception.

Besides questions of capacity and location, the expeller plants vary greatly in degree of sophistication. Not too many have facilities for cleaning, delinting cottonseed, and hulling (decorticating), and oilseed storage is generally deficient. Extraction and refining are combined in a few mills. Some also produce vanaspati.

The expeller extractive units have become important only since partition. Considerable expansion took place in the

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5/ *Ibid.*

Table 5.--Cottonseed and rape and mustard seed production in West Pakistan, by major political divisions, 1967-68. 1/

Major political division	Production 2/		
	Cottonseed 3/	Rape and mustard seed	Total
	- - - - - Long tons - - - - -		
Peshawar	560	15,000	15,560
D.I. Khan	660	7,000	7,660
Rawalpindi	9,200	10,000	19,200
Sargodha	150,680	26,000	176,680
Lahore	29,720	21,000	50,720
Multan	425,780	32,000	457,780
Bahawalpur	142,900	53,000	195,900
Khairpur	66,260	75,000	141,260
Hyderabad	193,000	28,000	221,000
Quetta	---	1,000	1,000
Kalat	---	1,000	1,000
Karachi	---	1,000	1,000
Total	1,018,760	270,000	1,288,760

1/ Division production data for peanuts and sesame seed not available.
2/ A long ton equals 2,240 pounds.
3/ Estimated from division data for lint cotton on a two to one basis.

Source: Yearbook of Agricultural Statistics, 1968. Fact Series No. VII. Food and Agriculture Division, Ministry of Agriculture and Works, GOP. Rawalpindi, January 1969.

fifties. The importation of expellers is now prohibited by law. Probably the more efficient foreign-make expellers could improve considerably the percent of oil extraction from oilseeds.

A sizeable portion of the available cottonseed, not held back for seed nor fed to cattle, is processed by the expeller plants. Perhaps the village mills process more of the rape and mustard seed than do the expeller mills. The mills, which also refine oil, process both crude cottonseed and soybean oil.

The third type of extraction is by the solvent method. Solvent extraction was introduced in Pakistan in the sixties. Solvent extraction is widely used in the developed countries. It now has a substantial development in India. According to Sproull, the possibility of the P.L. 480 program being discontinued, which would mean a large reduction in soybean oil imports, became a matter of policy concern to the Pakistan Industrial Credit and Investment Corporation in 1965. 6/ One approach was to finance several large solvent extraction mills on the theory they could extract oil more efficiently and this would insure a much larger supply of edible oil from domestic supplies of cottonseed. Sproull reported, " . . . ten solvent mills able to operate in West Pakistan . . . ," and that five more were in some stage of PICIC approval. The 10 mills have an annual production capacity of 60,000 long tons of oil.

Due to a complexity of conditions and circumstances, these 10 mills are producing very little cottonseed oil. Only one of the 10 is reported in successful continuous operation. Apparently three are not extracting oil; another three operate intermittently on cottonseed; and three of the smaller mills are only occasionally extracting oil from cake.

Since the solvent extraction process leaves only a very small residue of oil in the cake (under 1 percent of cake weight), it seems somewhat strange that the solvent mills are beset with financial difficulties. One analysis showed a small loss on a per day operational basis over the 1965-69 period. 7/ Some of the reasons cited shed light on problems which require study in making more viable the extractive oil industry in order to provide markets for any increase in oilseed production. The reasons cited in the Working Group Report are as follows:

6/ Pakistan Industrial Credit and Investment Corporation is a government agency which finances construction of large oil extraction mills.

7/ Report of the Working Group on the Problems of the Solvent Extraction Industry and Measures to make the Industry Profitable in West Pakistan. Copy made available through the Office of the Deputy Administrator, Farm Research, ARS, USDA.

1. Low average price of by-products. Parenthetically, there is no satisfactory market for linters, hulls, and soap stock. In the domestic market, solvent processed cake sells at a discount to cattle feeders.

2. Shortage of raw material. Parenthetically, this appears to be the major problem. Efficient processing requires volume from nearby producing areas so as to enable continuous operation most of the year.

3. Lack of protection. Parenthetically, the claim is made that the mills cannot buy cottonseed at prices low enough to compete with relatively low priced imported soybean oil.

4. The pioneer status. This is the infant industry argument that subsidization is needed in the beginning.

5. Discriminatory excise levy. Claim is made that the excise is on refined oil, hence only the solvent mills are liable in contrast to the expeller and village plants.

6. Lack of cushion.

7. Credit curbs. Solvent mills need more operating capital than other types of extractive mills and interest rates are very high.

8. Lack of other facilities. Claim is made that commercial warehousing for cottonseed storage is beyond the means of the mills to finance.

SUMMARY AND CONCLUSIONS

There is considerable evidence to support the general contention by Sproull and others that West Pakistan has sufficient capacity for extracting oil from oilseeds and refining the crude oil. Presumably this would hold even though oilseed production was increased to the point that West Pakistan became self sufficient in edible oils. It is further contended that the lack of a viable oilseed processing industry is due to other factors.

The priority factors would seem to be governmental policies, low-priced imports of soybean oil, and lack of satisfactory domestic markets for oilseed by-products.

Clearly, some changes in policy could help to improve the competitive status of the expeller and solvent mills.

The issue of phasing out imports of P.L. 480 soybean oil cannot be so readily resolved. Is West Pakistan willing to subsidize increased production of oilseeds to the point that imports of soybean oil would not be necessary? Would it be preferable for West Pakistan to concentrate on export crops in lieu of oilseed crops and use the foreign exchange earnings to buy oilseed or oil imports? Only additional study can provide the answers. Indeed, there may be no clear-cut answer.

The problem of low prices and limited demand for oilseed by-products will, perhaps, clear up in time. Education and research should help in convincing cattle feeders the value of cake without oil and the bulk value of hulls. Some imagination in merchandising should prove useful. West Pakistan now has some new industries which use linters as a raw material.

Considerable change in the oil extraction industry in West Pakistan is likely, provided increased oilseed production occurs. There appears to be something irrational about village mills competing favorably for cottonseed supplies compared with the expeller mills when the latter recovers about 90 percent of the oil compared with about 67 percent for the village mills. After all, the oil is the most valuable of the oilseed products. Perhaps the explanation is that, under the circumstances, the expeller (and solvent) extractive mills are not so efficient in other respects.

The commercial test for efficiency is unit cost of production. Large-sized plants, maintenance of an adequate volume of raw material to enable near year-round operations, proximity to oilseed producing areas, and efficient machinery, management, and operations all tend towards low unit costs. The available literature indicates various deficiencies in these respects. The leverage provided by increased supplies of oilseed for processing could assist materially in improving efficiency of output, especially in the larger mills.

SUPPLY AND DEMAND OF OILSEEDS AND OILSEED PRODUCTS IN WEST PAKISTAN

ACREAGE, YIELD, AND PRODUCTION

The total land area cultivated in West Pakistan has been gradually increasing in the last two decades (Table 2, Page 9). In contrast, there has been no increase in the area cultivated in East Pakistan. About one-fourth of the cultivated area in West Pakistan is left in "current" fallow each year whereas, in East Pakistan, 10 percent or less is fallowed. On a year-round

basis, double cropping is much more common in East than West Pakistan. Even so, from 12 to 15 percent of the cropped area has been "sown more than once" in West Pakistan in recent years.

Crop data for Pakistan are available for only four of the eight oilseed crops under consideration. In terms of acreage, cotton is West Pakistan's most important Kharif crop, but is probably second to rice in terms of value of production (Table 6). Peanuts and sesame are considered minor Kharif crops. Rape and mustard are considered the third most important Rabi crops (Table 6).

Acreage in these four oil crops increased 11 percent from the 5-year (1960-61 to 1964-65) average to 1966-67. The comparable increase in total cultivated acreage was 14 percent. Cotton acreage has been gradually increasing in recent years (Table 7). Rapeseed acreage, like that for cotton and cottonseed, increased substantially from 1966-67 to 1967-68. Actually, rapeseed and mustard had maximum acreages in the 1955-69 period. Percentage-wise, peanut acreage and production has expanded more than that for any other oil crop in the last eight years. Sesame acreage has gradually increased, judged by comparing 5-year averages, but some early 1960 acreages exceeded the 1967-68 estimate.

Crop statistics for West Pakistan tend to bear out the notion that less than one-half of the land cultivated is cropped during the Kharif season. The total harvested acreage in Kharif and miscellaneous crops was 15,465,000 acres in 1966-67 (Table 7). In estimating total land cropped in the Kharif season (not total acres of Kharif crops, which involves some double cropping), the difference between planted and harvested acres and acres in crops not reported must be considered. Together this is not likely to equal anything like 8,865,000 acres, which would bring the 15,465,000 acre estimate up to 50 percent of the 48,660,000 acres of total acres cultivated (Table 2, Page 9). The value of this observation would seem to be that a large Kharif fallow acreage is available for planting oilseed or other crops provided some of the limiting factors could be mitigated or solved.

Oilseed Crop Data

Cottonseed -- Under present conditions in West Pakistan, cottonseed is by far the most important domestic source of edible vegetable oil, cake, and meal (Table 7). Yields have increased only slightly in recent years. Average yield, in round numbers, for the 1965-66 to 1967-68 period was 500 lbs. per acre. 8/

8/ See Table 3 for oilseed products output per acre. This yield of 500 lbs. was used in making the cottonseed projections.

Table 6.--Crop acreages in West Pakistan, selected years.

Crops by season	Five year average 1/	1965-66	1966-67	1967-68
Kharif crops	- - - - -	Thousand acres	- - - - -	
Rice	3,075	3,443	3,483	3,508
Cotton	3,459	3,858	4,003	4,411
Millet	2,017	2,075	2,069	2,258
Maize	1,185	1,339	1,368	1,502
Sorghum	1,249	1,467	1,380	1,444
Sugarcane	1,158	1,476	1,605	1,245
Mung	170	178	165	200
Masoor	201	145	206	193
Tobacco	110	144	177	174
Ground nuts	33	58	84	125
Mash	96	82	85	114
Sesame	82	70	75	79
Chillies	59	46	44	60
Potatoes	39	42	47	50
Total	12,933	14,423	14,791	15,363
Rabi crops				
Wheat	12,316	12,738	13,205	14,785
Gram	2,893	2,643	3,074	2,769
Rapeseed 2/	1,189	1,091	1,136	1,340
Barley	460	382	400	429
Linseed	14	15	16	18
Total	16,872	16,869	17,831	19,341
Miscel. crops				
Miscel. 3/	*73	65	61	N.A.
Vegetables 4/	275	285	269	N.A.
Fruits	N.A.	357	*384	N.A.
Total	---	707	674	---

1/ Annual average for 1960-61 to 1964-65.
2/ Includes mustard seed.
3/ Includes garlic, onions, arhar and sannhemp which are mostly Kharif crops.
4/ Excludes potatoes.
* Approximate.

Source: Yearbook of Agricultural Statistics 1968. Fact Series No. VII, January 1969. Ministry of Agriculture and Works, Government of Pakistan.

Table 7.-- Acres, production, and yields for edible oilseed crops, West Pakistan, recent years. 1/

Crop and item	Unit	Five year avg. 2/	1965-66	1966-67	1967-68
Cottonseed					
Area	1,000 acres	3,459	3,858	4,003	4,411
Production	1,000 long tons 3/	704	816	912	1,019
Yield per acre	maunds 4/	5.5	5.6	6.2	6.3
Yield per acre	pounds	453	461	510	518
Rape and Mustard Seed					
Area	1,000 acres	1,189	1,091	1,136	1,340
Production	1,000 long tons 3/	217	179	200	270
Yield per acre	maunds 4/	4.9	4.5	4.8	5.5
Yield per acre	pounds	403	370	395	453
Peanuts					
Area	1,000 acres	33	58	84	125
Production	1,000 long tons 3/	17	29	46	73
Yield per acre	maunds 4/	13.7	13.6	14.9	15.9
Yield per acre	pounds	1,127	1,119	1,226	1,308
Sesame					
Area	1,000 acres	82	70	75	79
Production	1,000 long tons 3/	9	7	7	9
Yield per acre	maunds 4/	2.9	2.7	2.5	3.1
Yield per acre	pounds	246	224	209	255

1/ Statistics are available for only four edible oil crops. Linseed is not classified as edible although data are available. Apparently yields were calculated before acreage and production estimates were rounded to the nearest thousand.

2/ Annual average for 1960-61 through 1964-65.

3/ English long tons of 2,240 pounds.

4/ One maund equals 82.286 pounds.

Source: Yearbook of Agricultural Statistics (Fact Series No. VII, Jan. 1969). Ministry of Agriculture and Works, Government of Pakistan.

The demand for lint cotton as the major raw material for manufacturing textiles is likely to continue to increase in West Pakistan. Thus, cottonseed production will probably increase on the basis of more acres planted to cotton and higher yields of lint and seed. However, from the point of view of edible oil, cake, meal, and protein output per acre, cottonseed does not compare favorably with a number of other oilseed crops.

Peanuts -- Groundnuts rank as a low third in oilseed production in West Pakistan (Table 7, Page 24). More recent crop statistics indicate that the average dropped back to 86,000 in 1968-69 from 125,000 acres in 1967-68. In a campaign launched by the GOP to "Grow More Oilseeds," 9/ the West Pakistani peanut production goal was set at 100,000 long tons for 1968-69. Instead, production dropped from 73,000 tons in 1967-68 to 52,000 tons the following year. One analyst observed that most crushing mills were without shellers and were not prepared in other ways to produce peanut oil. 10/ In consequence, prices received by farmers dropped and plantings declined.

In the last 5 years, peanut yields have been gradually increasing (Table 7, Page 24). However, yields were higher in the early fifties and sixties. In making the per acre peanut oil and cake and meal estimate, a yield of 1,275 lbs. was used (Table 4, Page 14). The 1966-68 weighted average yield was 1,242 lbs. 11/

Expansion of peanut production is likely to be slow until such time as a sufficient number of processing plants are equipped to produce a peanut oil vanaspati (vegetable ghee) which is more palatable to the consumer. Net returns per acre to the producer will probably be much higher when peanut oil becomes more widely accepted by consumers.

Rape and Mustard Seed -- Some recent increases in acreage are noted; however, the level is still below acreages for this seed crop in the late fifties. Recent yields are higher than in

9/ Source is a USAID/Lahore Report of the Working Group on the Problems of the Solvent Extraction Industry and Measures to make the Industry Profitable in Pakistan. Unpublished 1969 manuscript, pp. 4-5.

10/ USAID/Lahore. Edible Oil Industry in Pakistan. John Sproull. Sept. 1970. Unpublished manuscript. The author reports peanut oil hydrogenates very well thru the solvent process, but that only one such plant has so experimented. For peanut oil to be acceptable for making vegetable ghee, deodorizing is essential. The large number of small crushing mills in West Pakistan are not equipped to deodorize.

11/ Calculated from data in Table 6.

the fifties and the 1967-68 production set a record at 270,000 tons (Table 7, Page 24). Rape and mustard seed ranks third among Rabi crop acreages (Table 6, Page 23).

Continued large scale production of rape and mustard seed is likely for several reasons. It fits nicely into rotations as a 4-month Rabi crop when the land is not sown to wheat. Probably it can compete advantageously with gram. The existing oil crushing mills in West Pakistan are experienced in processing the seed and there is plenty of crushing capacity available when the oilseeds are harvested.

There are some deterrents to any substantial increases in production of rape and mustard seed in West Pakistan. The oil is not used in the production of vanaspati, which is by far the most important way of consuming edible oils in West Pakistan. In consequence, a considerable percent of the oil is shipped via Karachi and boat to East Pakistan. Total shipping costs run high. Also, this seed is a relatively low per acre producer of oilseed products. There seems little basis for assuming that net per acre returns to producer will increase substantially without higher yields and improved efficiency in extracting the oil.

Safflowers -- No acreage data for safflowers in West Pakistan are available. Yield data in Table 4 are based on experience in Arizona and California in the U.S. In those States, the crop is grown under irrigation and yields ranged from 1,850 to 2,650 lbs. per acre in the 1966-69 period. The assumed lower yield of 1,500 lbs. discounts for anticipated varietal and agronomic problems. However, the more adventurous producers probably would apply modern technology in growing the crop, with the result that yields would average higher than if traditional cultivation practices were applied.

Safflower oil has proven very acceptable to consumers in the United States and Japan. Output per acre of oil and cake and meal compares favorably with most other oilseeds (Table 4, Page 14). Introduction of the crop, assuming its agronomic adaptability, and acreage expansion may take several years before safflower could become one of the more important oilseed crops in West Pakistan.

Sesame or Sesamum -- This crop is well established on a small and subsistence basis in both parts of Pakistan. Acreage, yields, and consumer demand for the seed and its oil are higher in East than in West Pakistan. Sesanum, with a seed yield of about 245 lbs. per acre (Tables 4 and 7), does not appear to have much potential in commercial agriculture.

Soybeans -- Experience in growing soybeans in West Pakistan, outside of certain experiment stations, is limited and yield

data are not available. As assumed yield of 12 quintals per hectare converts to 1,070 lbs. per acre. This yield is two-thirds of the 1968 U.S. yield, but is higher than recent yields reported for Brazil, Thailand, Turkey, Vietnam, the Republic of Korea, and Indonesia. 12/ Japan reported a yield of 1,229 lbs. per acre in 1968 and Taiwan 1,318 lbs. the same year. Adoption of improved short season (120 days) varieties and modern technological practices are assumed.

The acceptability of soybean oil to West Pakistani consumers is well established, judging by the amount imported and used in vegetable ghee. The crop has wide climatic and soil tolerances and some producers have had limited experience in growing the crop. 13/

Soybeans have considerable potential from an agronomic point of view. Oil production from soybeans is fairly satisfactory, even though surpassed by peanuts, safflowers, and sunflowers. As a source of cake and meal for export, it ranks next to safflowers.

However, some changes will be necessary before soybeans can be expected to become an important crop in West Pakistan. First, a build-up of expeller or solvent-type crushing mills, which can operate at fairly efficient levels, appears essential. The small local ghanis or kohlus crushing mills are not equipped for efficient processing of cake and meal. Estimates vary as to the percentage, but considerable oil is left in the cake and meal. The same inefficiency in oil extraction holds for the small, but even more numerous, village crushing mills. The build-up points in the direction of large expeller-type mills.

Second, some pricing policy adjustments appear necessary before domestic soybean production can be expected to obviate the need for importing soybean oil. The preliminary indications are that domestic soybean production cannot compete with soybean oil imports on a laissez faire basis. The range of policy alternatives to the GOP are considerable, among which are subsidies,

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12/ FAO, Production Yearbook, 1969.

13/ In Dec. 1970, the writer had occasion to interview Dr. Malik Mohamed Murtaza Shariff, a Ph.D. in Botany, who is associated with the Dept. of Plant Pathology, Agricultural College, Tandojam, West Pakistan. He reported that a few years ago, a few of the agricultural colleges developed a soybean variety suitable for certain areas in West Pakistan. Enough seed was produced to distribute to farmers and a good crop was harvested on a limited acreage. He reported that crushing mills based their prices on imported soybean oil equivalent prices. These prices were too low to induce production. Part of the reason for the low prices was the crushing mill operators were not geared for processing soybeans. The following year producers lost interest in soybeans as an alternate crop.

import controls and duties, minimum farm price programs, and programs to improve efficiency in processing and marketing of the oilseed crops.

Sunflowers -- No official statistics on sunflowers are available. One private enterprise interested in processing oilseeds has been promoting the production of sunflower seed. This company has financed seed development and production on its own farm in the Multan area since 1965. 14/ The company representative indicated selective breeding had brought yields up to 2,500 lbs. per acre. "He suggested that 12-15 maunds per acre . . ." would be a more normal expectancy. Further, he believed something less than 8,000 acres of sunflower seed was planted in 1970. More plantings were forecast in 1971.

Many years ago, experiments on sunflower seed varieties were started at the Government Research Institute at Lyallpur and Tando. 15/ However, no yield data are available.

For purposes of estimating oil and cake and meal output per acre from sunflower seed, an assumed yield of 890 lbs. was used. This figure is conversion from 10 quintals (quintal here equals 100 kilos) per hectare. This yield was based upon a review of data for other countries.

According to FAO's Production Yearbook 1969, the USSR averaged 13.3 quintals per hectare for the 3-year period, 1966-68. Argentine yields in recent years averaged slightly under 9 quintals. Recent yields in Turkey averaged slightly under 10 quintals and those in South Africa about 5.5 quintals.

In the U.S. two states make sunflower crop estimates -- North Dakota and Minnesota. Since 1965, acreages have been increasing and 224,000 acres were harvested in 1969. Yields for the U.S. for 1966-68 averaged 9.8 quintals per hectare. In 1967 a maximum yield of 11.9 quintals per harvested hectare was estimated for North Dakota.

There are several factors favorable to production of sunflower seed in West Pakistan. Of the oilseed crops under consideration, it ranks third in oil output per acre and fourth in cake and meal. It can be produced as a Rabi crop and per acre output runs considerably higher than that for rape and mustard seed, the other Rabi oilseed crops. Varietal work is in progress. Perhaps the most important thing is that an industry firm is pushing sunflower seed production. Good seed, advice on how to

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14/ See USAID Memorandum of Conversation. Islamabad. Nov. 12, 1970. Page 3. Dr. S. Malik represented Lever Brothers (Pakistan) at the meeting.

15/ See newspaper article cited in note 1.

grow and harvest the crop, and a market for the harvested product are essentials being provided.

There are two additional factors which affect prospects. One is the price farmers would receive. As of April, 1970, the company promoting sunflower production was willing to purchase sunflower seed for 25 Rupees per maund (82.29 lbs.). Data are needed to determine net returns per acre. On the basis of 25 Rupees per maund, gross returns on a yield of 890 lbs. would amount to 270.5 Rupees, or $56.80 per acre. 16/

The other factor is consumer acceptance of sunflower oil for cooking and as a basic ingredient in vanaspati. So far, West Pakistani consumers are practically without experience with this oil. However, available literature does not indicate any de-odorizing or toxic problems.

Mustard -- See Rape and Mustard Seed.

EXPORTS AND IMPORTS OF OILSEEDS AND OILSEED PRODUCTS

In terms of effective demand, Pakistan is deficient in edible oilseeds and oils, but has an exportable surplus production of animal feed concentrates. In recent years, Pakistan has been importing substantial amounts of soybean oil (Table 8). Though less in tonnage, animal oils are important regular imports. Coconut oil imports rank second to soybeans on a weight basis. Of the inedible oils, a few thousand tons have been imported in recent years. Of these, linseed oil is the most important.

Pakistan is also a net importer of oilseeds (Table 8). These imports have been decreasing in recent years. Only rape and mustard seed and copra are regularly imported.

While Pakistan is a net importer of oilseeds and oils, it exports cake and meal (Table 8). The principal cake and meal sources are cottonseed, rape and mustard seed, and peanuts. Protein contents of the exported cake range from 30 to 50 percent. Another characteristic of most of the exported cake is the high oil content. Some observers report that European mills extract the oil from cake imported from Pakistan before the cake is consumed as an animal feed concentrate.

Vegetable fats and oils imports, on a value basis, amounted to 4.5, 10.2, and 8.1 million dollars in 1965, 1966, and 1967

16/ Exchange rate of 4.762 Rupees per dollar used.

Table 8. --Pakistan: Volume of exports and imports of oilseeds and oilseed products, 1965, 1966, and 1967

Item	SITO Code	Exports 1965	Exports 1966	Exports 1967	Imports 1965	Imports 1966	Imports 1967
		Metric Tons					
Oilseeds	22						
Ground nuts, total, green, shelled basis	221.1	530	---	---	6,360	---	30
Copra	221.2	---	---	---	1,500	440	4,080
Palm nuts and kernels	221.3	---	---	---	---	---	85
Cotton seed	221.6	351	460	127	4,779	---	62
Castor-oil seed	221.7	---	---	---	---	---	1
Rape and mustard seed	ex.221.8	331	606	514	20,400	18,000	4,342
Sesame seed	ex.221.8	---	---	12	---	---	---
Total reported in Yearbook		1,212	1,066	653	33,039	18,440	8,600
Animal and vegetable oils and fats	4						
Animal oils and fats	41						
Oils of fish and marine mammals	411.1	---	---	1	267	270	118
Animals oils, fats, and greases ex. lard	411.3	---	---	---	29,230	21,550	43,680
Total reported		---	---	1	29,497	21,820	43,798
Fixed vegetable oils and fats	42						
Soybean oil	421.2	---	---	---	91,049	26,900	83,400
Cotton seed oil	421.3	---	---	---	9,378	9,600	4
Ground nut oil	421.4	---	---	---	2	---	6
Olive oil	421.5	---	---	---	128	---	170
Sunflower-seed oil	421.6	---	---	---	---	---	1,104
Rape, colza and mustard oils	421.7	---	---	---	---	---	2,260
Linseed oil	422.1	69	11	19	3,192	2,126	917
Palm oil	422.2	---	---	---	---	---	2,482
Coconut oil	422.3	---	---	---	11,731	15,727	13,437
Palm-kernel oil	422.4	---	---	---	---	---	25
Castor oil	422.5	25	19	22	28	1	12
Tung oil	ex.422.9	---	---	---	4	---	6
Total vegetable oil reported		94	30	41	115,512	54,354	103,823
Oil seed cake and meal, and other vegetable oil residues	081.3	47,070	71,480	74,330	110	---	---
Ground nuts, cake and meal	ex.081.3	3,000	9,300	10,420	110	---	---
Copra, cake and meal	ex.081.3	---	---	1,770	---	---	---
Linseed, cake and meal	ex.081.3	---	2,400	1,750	---	---	---
Cotton seed, cake and meal	ex.081.3	17,000	37,360	36,940	---	---	---
Rapeseed, cake and meal	ex.081.3	17,000	15,310	11,830	---	---	---
Oil seed, cake and meal	ex.081.3	10,070	6,900	3,000	---	---	---
Total cake and meal reported		47,070	71,270	65,710	110	---	---

respectively. 17/ Comparable imports amounted to 44.8, 37.2, and 23.7 million dollars. Export values of vegetable fats and oils were 10 percent, 27 percent, and 34 percent of comparable imports in the three years. The increasing relative importance of exports, as offsets to imports, was due to decreasing imports rather than to increasing dollar values of exports.

The export value of cake and meal and other vegetable fats and oils amounted to less than 2 percent annually of all merchandise exports in the 1965-67 period. The value of soybean oil and other imports of fats and oils dropped from 4.3 percent of all merchandise imported to 2.2 percent in 1967.

Just how important are vegetable oil imports in terms of domestic consumption of vegetable oils? Satisfactory data for West Pakistan are not available, but a very rough answer, on a weight basis, can be provided for all of Pakistan. During the nine-year period, 1961-69, vegetable oil imports, including equivalents of oil in oilseeds, contributed from 23 to 41 percent of the domestic consumption of vegetable oils. 18/ Some dropping off in importance of imports may have occurred since the 1965 peak of 41 percent. In 1968 and 1969, imports amounted to 30 and 31 percent respectively.

SUPPLY-DEMAND AND DISPOSITION

With one year's exception, since 1965, the visible supply of edible fats and oils for all of Pakistan has been about 500,000 long tons or more (Table 9). The supply comes from domestic production and imports, and consists of both animal fats and vegetable oils. Inedible fats, such as inedible offal, and oils such as linseed and tung are excluded. However, it should be noted that not all edible fats and oils are used for human consumption. In processing, some residuals are diverted to industrial uses ranged from 17 to 21 percent in 1965-69 (calculated from Table 9 data).

Probably crop production and foreign trade statistical data are among the more reliable series for Pakistan. Less reliable are estimates of percents of seed crushed, oil content of the seed, and edible oils used for industrial purposes.

In considering the situation for West Pakistan, no import data, as such, are available. Further, the total amount of oil

17/ FAO, Trade Yearbook, 1969. Page 521.

18/ Source: Trade Data: Semi-Annual Oil World and Van Doorn, Annual. Tabulation reported as an attachment to USAID/Islamabad "Memorandum of Conversation," Nov. 12, 1970. The memorandum evolved as a report of a "Work Group" meeting on "Overall mission policy with respect to oilseeds and edible oils."

Table 9.--Estimated production and imports of edible fats and oils, Pakistan, 1965-69.

Item	1965	1966	1967	1968	1969
	1,000 long tons				
Production					
Animal fats	135	135	135	135	135
Vegetable oils	186	192	215	258	246
Total	321	327	350	393	381
Imports					
Animal fats	29	26	43	45	121
Vegetable oils	131	58	132	110	109
Total	160	84	175	155	130
Total visible supply	481	411	525	548	511
RECAPITULATION					
Vegetable oils					
Produced	186	192	215	258	246
Imported	131	58	132	110	109
Total	317	250	347	368	355
Animal fats					
Produced	135	135	135	135	135
Imported	29	26	43	45	21
Total	164	161	178	180	156
RECAPITULATION					
Edible					
Animal fats	126	125	125	125	125
Vegetable oils	271	201	291	315	301
Total	397	326	416	440	426
Industrial					
Animal fats	39	36	53	55	31
Vegetable oils	46	49	56	53	54
Total	85	85	109	108	85

Source: Table 1 with parts I and II, attached to USAID/Islamabad "Memorandum of Conversation," Nov. 12, 1970. The memorandum reported on a Work Group session concerned with oilseeds and edible oils in Pakistan.

Table 10.-- Apparent consumption of edible oils in West Pakistan and estimated oil produced from West Pakistani oilseed crops, 1965-68.

Item	1965	1966	1967	1968
1. Estimated per capita consumption 1/ (lbs.)	5.9	4.3	6.0	6.4
2. Population 2/ (1 mil.)	52.0	52.8	53.8	54.8
3. Total consumption (1 mil. lbs.)	306.8	227.0	322.8	350.7
4. Amount of oil from West Pakistan crops 3/ (1 mil. lbs.)	269.5	261.2	295.4	367.8
5. Additional supply required 4/	37.3	-34.2	27.3	-17.1

1/ The estimated per capita edible oil consumption for all of Pakistan is increased 10 percent. This assumes more fats and oils are consumed in West Pakistan than in East Pakistan. On this basis, West Pakistani per capita consumption was 20 to 23 percent higher than in East Pakistan.

2/ Population projections for West Pakistan are supplied by the Far East Branch, Foreign Regional Analysis Division, ERS, USDA.

3/ See Table 11, col. 7. Data are converted from long tons to millions of pounds.

4/ Exports to East Pakistan would increase the supply needed. Apparently East Pakistan does not ship any edible oils to West Pakistan.

shipped to East Pakistan is not available. Hence, it does not appear satisfactory to develop a table parallel to Table 9 for West Pakistan.

A somewhat arbitrary approach to estimating consumption of edible oils and fats in West Pakistan appears to be more indicative. First, consumption in West Pakistan is estimated on the basis of an adjusted per capita consumption of edible oils for all of Pakistan (Table 10). Animal fats are excluded. On this basis, West Pakistan consumption ranged from 227,000 long tons in 1966 to 351,000 tons in 1968 (Table 10).

The second step was to estimate edible oil production from oilseed crops grown in West Pakistan (Table 11, Page 35) and then to compare these estimates with consumption (Table 10, Page 33). Over the four years studied, domestic oil production just about balanced with the estimated consumption. The important missing consideration is the amount of oilseeds or oils shipped to East Pakistan, which is the more deficient area. One source indicated that about 85,000 tons of rapeseed and other oilseeds excluding cottonseed were shipped annually to East Pakistan. 19/ Probably West Pakistan has more than offset these shipments of oilseeds and oils to East Pakistan by imports, the most important of which has been soybean oil. Actually some of the Karachi imports may be reexported in blended form to East Pakistan.

Thus one approach to establishing a goal or measure of just how much West Pakistan should increase oilseed crop production could be to aim at offsetting the tonnage of edible oil imports. One source cites Karachi imports of edible oils as follows 20/:

1965-66	48.6	thousand	long	tons
1966-67	27.1	"	"	"
1967-68	41.4	"	"	"
1968-69	61.7	"	"	"

Assuming the need offset oil production in West Pakistan to be 62,000 long tons, this could be done by increasing cottonseed production by 861,000 l.t. This would require increasing harvested acres for cotton by 3,717,000 acres, or by 84 percent.21/

19/ Karachi Port Trust. Unpublished data. See Table 35 accompanying Sproull report cited in footnote 10. Probably 85,000 l.t. of rapeseed would produce about 28,000 tons of oil.
20/ Karachi Port Trust. Unpublished data. See Table 69 accompanying Sproull report cited in footnote 10. These data are not interpreted as being total edible oil imports for consumption in West Pakistan.
21/ Based on assumptions used in Table 12. This showed 7.2 lbs. of oil per 100 lbs. of cottonseed produced.

Table 11.--Estimated oil production from four oilseed crops produced in West Pakistan, 1965 thru 1968.1/

Year	Production	Seed crushed: Percent	Seed crushed: Amount 1 x 2	Oil production: Percent of crush	Oil production: Total 3 x 4	Oil production: Industrial Pct. x 5	Oil production: Edible Pct. x 5
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	1,000 t.	Pct.	1,000 t.	Pct.	1,000 t.	1,000 t.	1,000 t.
	Cottonseed					(20%)	(80%)
1965 ..	742	60	445.2	15	66.8	13.4	53.4
1966 ..	816	60	489.6	15	73.4	14.7	58.7
1967 ..	912	60	547.2	15	82.1	16.4	65.7
1968 ..	1,019	60	611.4	15	91.7	18.3	73.4
	Rape and mustard seed					(2%)	(98%)
1965 ..	212	90	190.8	33	63.0	1.3	61.7
1966 ..	179	90	161.1	33	53.2	1.1	52.1
1967 ..	200	90	180.0	33	59.4	1.2	58.2
1968 ..	270	90	243.0	33	80.2	1.6	78.6
	Peanuts					(5%)	(95%)
1965 ..	20	50	10.0	28	2.8	0.1	2.7
1966 ..	29	50	14.5	28	4.1	0.2	3.9
1967 ..	46	50	23.0	28	6.4	0.3	6.1
1968 ..	73	50	36.5	28	10.2	0.5	9.7
	Sesame seed					(15%)	(85%)
1965 ..	9	80	7.2	40	2.9	0.4	2.5
1966 ..	7	80	5.6	40	2.2	0.3	1.9
1967 ..	7	80	5.6	40	2.2	0.3	1.9
1968 ..	9	80	7.2	40	2.9	0.4	2.5
	Total Production						
1965 ..	983	---	653.2	---	135.5	15.2	120.3
1966 ..	1,031	---	670.8	---	132.9	16.3	116.6
1967 ..	1,165	---	755.8	---	150.1	18.2	131.9
1968 ..	1,371	---	898.1	---	185.0	20.8	164.2

1/ Tons are long tons weighing 2,240 lbs. each.

Sources: Production data are official estimates of GOP, Yearbook of Agricultural Statistics, 1968. Percentages are drawn from Tables 1 and 3 and are attached to "Memorandum of Conversation" cited in footnote 18.

If the increased production of 62,000 tons of oil were obtained through sunflower production (classified as a possible year round crop), a harvest of 227,000 long tons of seed and 572,000 harvested acres would be required. 22/

No attempt has been made to review in this report all of the supply and consumption estimates available. The U.S. agricultural attache has made supply, consumption, and stocks estimates for edible oils for all of Pakistan on a fiscal year basis for 1968-69, 1969-70, and 1970-71. 23/ While the attache data are not directly comparable to tabulations on a calendar year basis, his data and the data in Table 9 appear fairly consistent when beginning and end stocks are taken into consideration.

The Ministry of Agriculture and Works, GOP, has estimated vegetable oil production for East and West Pakistan on a fiscal year basis. 24/ His data show higher oil production than do the estimates in Table 11, page 35. Differences are probably due to assumptions of the percent of cottonseed and peanuts which are crushed and the percent of oil extractable from rape and mustard seed.

Another approach to estimating total supply needs for fats and oils in West Pakistan, over amounts supplied from domestic production, can be based on per capita consumption of grams of fats and oils per day. FAO estimates the fat content of foods consumed per capita in Pakistan to equal 16 grams per day. 25/ Available data for 1968 and 1969 suggests 10 grams per day is a more reliable estimate for edible fats and oil. The FAO estimate for India is about 11 grams; for the Philippines, 8 grams; and for Afghanistan, 8 grams. In most developed countries, consumption runs 55 grams or more per day. In some intermediate countries, the consumption is more modest. Examples are: Costa Rica, 25; Brazil, 15; Iran, 18; Turkey, 22; and Taiwan 17 grams per capita per day.

Perhaps a reasonable short run objective for West Pakistan might be 20 grams per day of fats and oils from oilseed and animal fat sources. On this basis, the situation in 1968 would have been about as follows. With a population of 54.8 million people, fats and oils consumed would have been 393,728 l.t.

22/ It is assumed that 90 percent of the crop would be crushed. Oil content estimated at 32 percent, and 95 percent would be edible. Seed yield of 890 lbs. used.

23/ See Note 1. Reference above is to enclosure 2, a table on edible oil supply and distribution.

24/ Yearbook of Agricultural Statistics 1968. Fact Series No. VII Jan. 1969. Planning Unit, Ministry of Agriculture and Works, GOP. Rawalpindi.

25/ FAO Production Yearbook 1969. Table 135.

Discounting 19 percent for industrial use of edible fats and oils, then 486,084 tons would need to be produced.

Assuming production of animal fats and vegetable oils equaled 275,000 tons in West Pakistan in 1968 26/, an additional 211,000 tons would be needed to meet requirements.

What would be the additional oilseed production and acreage requirements if soybeans were expected to supply 211,000 tons of vegetable oil?

From a yield of 10 quintals per hectare or 1070 lbs. per acre of seed, 168.5 lbs. of refined oil could be expected. 27/ To produce 211,000 l.t. of refined oil, 2,805,000 acres producing 1,340,000 l.t. of soybeans would be required.

Of course different yield assumptions would give varying acreage and seed production requirements. One estimate in the oft cited "Memorandum of Conversation" suggested a soybean oil yield of 8 maunds, or 658 pounds, would be "representative". 28/ This would call for a seed yield of 4280 lbs. per acre or 46.8 quintals per hectare, which is completely unrealistic.

In considering domestic production, the deficit situation in East Pakistan should be considered. However, alternatives are such that it is not necessarily a must that West Pakistan continue to produce oilseeds for exporting edible oils to East Pakistan.

Nothing which has been written above should be construed as advocating discontinuance of West Pakistani edible oil imports. It has been shown that it could be done thru increased domestic production of oilseed crops. The feasibility of replacing these imports is both a GOP policy and economic matter. As a minimum, cost of production and price studies are needed.

CONSUMPTIVE PATTERNS AND PRODUCT PREFERENCES OF WEST PAKISTANIS

Consumptive patterns and product preferences for edible fats and oils in West Pakistan have been discussed above, but in scattered and incidental fashion. The purpose here is to review systematically, but briefly, these consumer characteristics.

26/ Based on vegetable oil production of 185,000 t. (see Table 11, page 35), and animal fats of 90,000 t. (two-thirds of production for all of Pakistan).

27/ In Table 4, a per acre return of 195 lbs. of oil was estimated. Here the purpose is to show how much oil would probably be available. Some seed would be held back for planting and there would be some waste (10% allowance). Refined oil is figured at 17.5 percent.

28/ See report cited in footnote 14, page 28.

At the time of partition (1947), West Pakistanis were consuming mostly ghee and vegetable oils from rape and mustard seed, sesame, and cottonseed. The pattern changed somewhat in the fifties when vegetable ghee (hereinafter referred to as vanaspati) came into production. The main oil source for vanaspati was cottonseed, but in the sixties, refined soybean oil also came to be used.

Apparently West Pakistanis have long preferred ghee to other fats and oils. Ghee is produced by heating churned butter so as to dehydrate the liquid fat. This enhances keeping qualities. Apparently demand came to exceed supply, which gave rise to ghee consumption being a "status" indicator.

Hydrogenation of certain vegetable oils proved acceptable in the fifties and vanaspati has in turn become a "status symbol." It, like ghee, is a semi-solid product. The most palatable vanaspati used in West Pakistan comes from refined oil -- mostly cottonseed and soybean oils. Peanut oil has proven less palatable except as it is deodorized. Very little, if any, of the oil from rape, mustard, and sesame seed is used in vanaspati.

The remainder of the edible vegetable oils are consumed as liquid oil in cooking and salads. Not all such oils are refined. This holds especially for "mustard" and cottonseed oils which are extracted in village mills and consumed locally.

For all of Pakistan, butter and ghee consumption averaged 24 percent of total edible fats and oils in the 1966-68 period. Other animal fats averaged 8 percent; vanaspati 24 percent; and liquid vegetable oils 44 percent. Since less ghee and butter and very little vanaspati are consumed in East Pakistan, it follows that butter, ghee, and vanaspati, when considered together, are much more important than is liquid oil in West Pakistan.

A considerable portion of the rape, mustard, and sesame seed, or their processed oils, produced in West Pakistan is shipped to East Pakistan. Thus, the bulk of vanaspati and liquid oil consumption in West Pakistan depends considerably on supplies of locally produced cottonseed and imported soybean oils.

As to East Pakistan, the most preferred edible oil for consumers is known as "mustard oil." Historically, this referred to an unrefined mixture of rape and mustard seed oils. Adulturation has taken place in recent years through additions of soybean oil. This was especially advantageous to the trade because of the higher prices paid for mustard oil in East Pakistan. Cheaper soybean oil added to the mix without appreciably affecting the palatability, gave larger profits to the trade since the adulturated mustard oil sells at prices almost equal to "pure"

mustard oil prices. However, unmixed soybean oil is imported and this product sells at a lower price.

Another aspect of the consumption pattern is that, in rural and village areas, liquid vegetable oils predominate. Vanaspati is brought in on very special occasions such as wedding feasts. Most of these oils are unrefined. The source of the oil varies, depending on local supplies of cottonseed, rape, and mustard seed, sesame, and peanuts. Some of the smaller expeller mills now buy soybean oil to mix with other oils.

In the cities, consumption of ghee, vanaspati, and refined oils, sold as liquid oils, predominate. In general, prices for these forms of edible fats and oils are cheaper in most urban areas than in the rural areas. Availability of supplies and greater purchasing power in urban areas help account for this relatively larger consumption.

In looking to the future, one might ask about consumer acceptance of other types of edible oils such as rice bran oil, corn oil, sunflower oil, and safflower oil. All could have possibilities, especially in supplying urban markets. Oils from rice and corn can be ruled out for the immediate future. Rice bran, with an oil content of about 10 percent, has to be processed quickly because of early deterioration. Only Japan, so far, is extracting oil from rice bran in commercial quantities. Corn oil extraction is associated with production of starch, and this industry is not important in West Pakistan.

The acceptability of soybean oil is well established. As a good but relatively cheap oil, it remains to be established whether or not domestic production of soybeans can compete with imported oil.

Sunflower and safflower oils are relatively untested by consumers in West Pakistan. Small amounts of sunflower oil have been imported from Russia, but consumer acceptability is not established. From the point of view of palatability, both sunflower and safflower oils will probably receive wide acceptability. As a polyunsaturated product, safflower oil sells at a premium in the United States and the U.S. has a small, but established, export market in Japan for the oil. Consumer acceptability of sunflower and safflower oils in West Pakistan is likely to depend on prices at which these oils can be sold. These oils are not likely to compete as imports with soybean oil. It becomes, in the long run, a matter of unit cost of production of seed and the comparative economic advantage of these seed crops.

SAFFLOWER

SAFFLOWER FOR WEST PAKISTAN 29/

Safflower (*Carthamus tinctorius* L.) merits thorough evaluation as an oil crop for West Pakistan. The reasons are: 1) safflower has been an oil crop of the West Pakistan-India-East Pakistan area for several centuries; 2) safflower has been successfully introduced to new areas during the last 20 years, including the United States, Australia, Mexico, and Spain; 3) safflower offers a range of quite different oils with very different uses; 4) the meal is an acceptable protein feed for ruminants; and 5) a related wild species, *C. oxyacantha* M.B., is a successful weed in northern areas of West Pakistan.

Research on safflower in West Pakistan should determine the following: 1) the potential of safflower entries in the World Safflower Collection; 2) the potential of segregating materials from crosses of superior entries to varieties from the United States with high oil contents; 3) the value of the wild species, *C. oxyacantha*, as a resource in the breeding program; 4) the best cultural practices for superior materials in areas where safflower is adapted; and 5) the utilization value of different safflower oils.

WORLDWIDE PRODUCTION OF SAFFLOWER

Compared to other oilseed crops, safflower is of minor importance, so minor that worldwide production data are scarce and not too reliable. India has the largest planted acreage, estimated to be about 405,000 hectares in 1955 and 526,000 hectares in 1961-62. Essentially all of it is grown as a dryland (rain fed) crop on the heavier soils of the Deccan in south central India. Annual rainfall, most of it coming during the summer monsoons, varies between 50 and 75 cm. Safflower is sown in October and November and is harvested in February and March -- that is the Rabi season. Often safflower is sown as a minor component of a mixture of crops, each being harvested separately as it matures. Yields in solid stands would vary between 200 and 1000 kg./ha. Essentially all of the seed is processed locally using *ghanis*.

Over much of the Middle East, from Afghanistan to Egypt and up the Nile to the Sudan and Ethiopia, safflower has been grown as a minor crop, usually for the flowers but, in a few instances

29/ P.F. Knowles, University of California, Davis, prepared this section for USDA Agricultural Research Service in January, 1971.

(Egypt, Turkey, and Afghanistan), for oil. Where it is used for oil, it is processed locally by primitive equipment.

Safflower has been successfully introduced into the United States, where the harvested acreage (1964-1970) has varied between 72,000 and 162,000 hectares. California is the leading state with the 1964-1970 area of production varying between 67,000 and 138,000 hectares. Safflower has been introduced and successfully grown as an oil crop in northwest Mexico, in Queensland, Australia, and in southern Spain.

In 1958, in West Pakistan, the author saw safflower in the Gujarat area, where it was grown as a mixture with other crops. It was used as a forage, being harvested green and fed immediately.

PRODUCTION POTENTIAL

Seed

During the period 1964-1970, commercial yields in the United States varied as follows:

California	1810-2357 kg./ha.
Arizona	2270-3079 "
Plains states	547-978 "

Under optimum irrigation conditions in California and Arizona, yields between 4500 and 5000 kg./ha. are possible. This would be true of Northwest Mexico also. When grown dryland, yields will usually range below 2000 kg./ha., except where abundant reserves of soil moisture are available, when yields may vary between 2000 and 3300 kg./ha.

Oil

Commercial varieties presently in use will contain between 38 and 42 percent oil (oven-dry basis), the more recently developed varieties generally being in the higher range. Experimental materials have up to 46 percent oil, and it is expected that such types will be in commercial production in a few years. Increases in oil content have been achieved mostly by reducing hull thickness. Types showing most promise have gray- to purple-striped seed.

Protein

Like oil, protein content has been increased as hull thickness has been reduced (Table 12). Purple-striped types should

yield a meal with a protein content around 30 percent. Obviously, as the oil content of the embryos (kernels) is increased, protein content will be decreased. The oil content of embryos will range from 50 to 65 percent.

Table 12.--Average composition of safflower seed of different genotypes (Rubis, 1967).

Genotype	Appearance of hull	Hull	Oil	Meal	
				Protein	Fiber
		Percent			
ThThStpStp	Smooth, white	40	39	20	41
ththStpStp	Very thin, gray	20	47	40	17
ThThstpstp	Brown striped	25	46	34	25

QUALITY OF THE OIL

The quality, and utilization, of safflower oil is governed in the main by its fatty acid composition. Currently two types are in commercial production, the high linoleic type and the high oleic type (Table 13).

Table 13.--Fatty acid composition of safflower oil from different genotypes (Ladd and Knowles, 1971).

Genotype	Designation	Fatty acid content			
		Palmitic	Stearic	Oleic	Linoleic
		Percent			
OlOlStSt	High linoleic	6-7	1-3	10-23	68-82
ololStSt	High oleic	5-6	1-3	77-80	13-16
ol^1ol^1StSt	Intermediate oleic	6-7	1-3	25-46	47-68
OlOlstst	High stearic	6-7	6-10	10-20	65-77
ololstst	High oleic-high stearic	4-5	5-6	72-78	12-18
ol^1ol^1stst	Intermediate oleic-high stearic	6-7	6-7	33-37	50-53

High Linoleic Oil

Over 98 percent of all safflower introductions to the United States and, until a few years ago, all commercial varieties had oil with high levels of linoleic acid. For many years this oil has been recognized as being of excellent quality for the manufacture of surface coatings, in part because it is resistant to yellowing. More recently it has been widely used in the manufacture of soft margarines. For other edible purposes, high linoleic safflower oil does not have wide use because of its tendency to produce polymeric materials from oxidative reactions. Still in dispute is the value of this type of safflower oil in reducing the incidence of athersclerosis because of its polyunsaturation.

High Oleic Oil

A mutant gene, ol, found in material that presumably originated in the area of the mouth of the Ganges River, switches the proportions of linoleic and oleic acids in safflower oil. High oleic oil (Table 13, Page 42) has high-temperature oxidative stability comparable to hydrogenated oils. High oleic safflower oil will be used primarily as a cooking oil, and will compete with hydrogenated vegetable oils obtained from several crops. It is possible that it will also be used as a source of oleic acid, which has a wide market for use in surface-active materials, lubricant additives, greases, cosmetics, alkyd resins, putties and sealants, and placticizers. UC-1, the first commercial high oleic safflower variety, will soon be replaced by several new varieties comparable in yield and oil content to high linoleic acid types.

Intermediate Oleic Oil

Not yet assessed for its utilization value is a type with intermediate levels of both oleic and linoleic acids. This type of oil (Table 13) is sensitive to temperature, oleic acid increasing with high temperatures and linoleic acid with cool temperatures.

High Stearic Oil

The gene st will raise stearic acid content from the usual levels of about 2 percent to from 6 to 10 percent. Combined with genes affecting proportions of oleic and linoleic acids, it is possible to produce a total of six different safflower oils (Table 13). Oils with higher levels of stearic acid have not been evaluated.

Color and Odor Problems

Unfortunately, brown-striped safflower seed, though having a high oil content, yields an oil that has a dark color and an undesirable straw-like odor. If temperatures are kept below 100° C. during processing, no pigment will form and the color precursor can be removed by extraction with water or through normal alkali refinement. The odor is complex in nature, with stinky, floral, musky, cedary, greasy, and beany components. The odors come from the hulls.

QUALITY OF THE PROTEIN

In general, the protein meal remaining after extraction of the oil has been equal to other oilseed meals, if comparisons are made on the basis of protein content. Undecorticated safflower meal has about five-sevenths of the net energy of cottonseed meal and five-eights of that of soybean meal. However, some shortcomings have been noted in the meal, and these are discussed below.

High Fiber Content

It is very difficult in processing safflower meal to reduce the fiber content below 5 percent, the upper limit that is acceptable for human consumption. However, if the seed is decorticated, it is possible to reduce the fiber content below 15 percent, the upper limit desirable for feeding to poultry and swine. Without decortication, the protein content of most commercial varieties is about 20 percent, somewhat less than for most oilseed meals. The hulls, which contribute to the high fiber content, have no feed value. If removed in processing, their disposal presents a problem.

Deficiency in Lysine

Safflower meal is deficient in lysine, and borderline for isoleucine and methionine. When the lysine deficiency was made up in rations for young chicks, there was no evidence of growth inhibitors and growth was faster than for optimally treated soybean meal with methionine added.

Ruminant animals can use most sources of protein without too much regard for amino acid composition. The microorganisms of the rumen have the ability to make their own amino acids from organic nitrogen in the diet, these in turn becoming available for the animal's use at a later stage in digestion.

A search of the World Safflower Collection indicated that there was some variation in levels of lysine, but not enough to be of much interest to the plant breeder.

Bitter Taste

Safflower meal has a bitter taste. When the bitter principl is extracted with acetone or alcohol, the meal has a characteristic mild flavor and a protein content of 70 percent.

Laxative Effect

Safflower meal has been found to have a laxative effect. The laxative principle, like the bitter principle, can be removed with alcohol.

GROWTH CHARACTERISTICS

Safflower seedlings do not grow aggressively, and their emergence can be easily retarded or prevented by adverse conditions. On emergence, the plant will remain in a rosette stage from 2 weeks if temperatures are high to 3 months if temperatures are low. This is a critical stage, because rapidly growing winter weeds or volunteer grain can grow ahead of the safflower and seriously reduce yields.

Once initiated, stems elongate rapidly and safflower becomes competitive with weeds. Stems may become 150 to 180 cm. high if seed is sown in early June. Stems reach their maximum height as flowering commences. Varieties vary in their degree of branching, most commercial varieties filling in rows spaced 75 cm. apart if reaching a height of 100 cm.

A second critical stage often occurs at flowering, when a deficiency of moisture may result in apparently vigorous plants producing few filled seeds.

Soil Requirements

Safflower has been most successful on deep, fertile, well-drained soils with neutral reaction. In such soils, the roots of safflower will penetrate to depths of 4 to 5 meters, and will remove essentially all of the available water down to 3 meters.

Under dryland conditions, safflower is similar to barley in its salinity tolerance, but under irrigation, it is slightly more sensitive than barley, cotton, or sugarbeets.

Heavy, clay-textured soils have presented problems at planting time in California. After winter rains, such soils are difficult to work and when they are worked up, they dry to form a cloddy seedbed to the depth of cultivation. In such situations, special planting equipment has been required which will push aside the clods and place the seed in moist soil in the bottom of the furrow covered by 2.5 to 5 cm. of soil. Crusts forming after seeding in heavy soil as a consequence of heavy rains will prevent emergence of seedlings and must be broken by harrowing.

Safflower has no ill effects on the soil. However, when the deeply penetrating roots exhaust the soil of water to depths of 3 to 4 meters, safflower will adversely affect the following crop if the water is not restored.

Safflower nutrient requirements are not precisely known. As a general rule, it will require 30 to 50 percent more nitrogen than small grains. When phosphorus is required by other crops, it has benefited by applications of 30 kg./ha. of elemental P. When potassium is scarce, it should be supplied at planting time.

Where safflower is grown without supplemental irrigation, or no rain occurs after planting, it is important that the fertilizer be applied deep enough in the soil to be available to the roots. In rice soils of California, good responses to P. have occurred when it was applied close to, and preferably just below, the seed where it was immediately available to the developing seedling.

Water

Irrigation water that has been satisfactory for most field crops has been satisfactory for safflower. Extra care in water management has been necessary for success in safflower production. Water management must take into account two characteristics of safflower: a) susceptibility to Phytophthora root rot and b) its deep root system.

Because of safflower's susceptibility to root rot, water must be managed to avoid ponding around the base of the plants. Susceptibility is also increased if plants are allowed to stress from lack of water to the extent that leaves begin to "fire."

Where a clay loam soil is supplied with water to field capacity to depths of 3 to 4 meters, the safflower plant can complete its entire development without supplemental water, giving yields of a metric ton or more per hectare. Maximum yields, however, cannot be achieved by this practice.

If water penetration of the soil is slow and the surface layers remain saturated for long periods after an irrigation,

losses from root rot will be severe. In most situations, such soils should not be used for safflower, not only because of difficulties in water management, but also because of poor root penetration.

Where the soil is sandy or shallow but drains readily, safflower will require about the same water management as other crops.

The following practices are recommended for most soils to avoid or to minimize damage from root rot:

a) Pre-irrigate to the expected rooting depth of safflower.

b) Plant varieties with most tolerance to root rot.

c) Plant on beds, and furrow-irrigate.

d) Irrigate in every other furrow, alternating the furrows with each irrigation.

e) Irrigate before the appearance of drought symptoms.

f) Avoid prolonged irrigations, especially during warm weather. The surface soil should be drained within 48 hours after commencing an irrigation.

g) Do not irrigate unnecessarily.

h) Provide complete surface drainage at the lower end of the field.

For maximum yields under irrigation, safflower will require between 75 and 110 cm. of water (including rain), depending on temperatures and soil textures. Where irrigations are given, they should continue past full bloom, otherwise seeds may fail to develop or to fill. Consumptive use rate (combined evaporation and transpiration) of safflower on a hot day in May in Arizona is nearly 1.25 cm., compared to 1.00 for cotton. For the season, consumptive use totals 113 cm. (Table 14).

Safflower does well on soils with a moderately high water table, providing the soil is permeable enough for good root penetration. Apparently because of its rapid root proliferation, it will thrive on the layer of about 30 cm. of moist soil above the water table.

Table 14.--Consumptive use of water for safflower grown at Mesa, Arizona, average 1958-1960 (Halderman, 1963).

Period	Stage of development	Centimeters of water
Jan. 16-30		0.46
Feb. 1-14		1.09
Feb. 15-28		2.13
Mar. 1-15	13 cm., Mar. 10	3.43
Mar. 16-31		6.50
Apr. 1-15	40 cm., Apr. 2	12.19
Apr. 16-30	75 cm., budding, Apr. 12	16.76
May 1-15	Flowering, May 10	17.91
May 16-31		19.10
June 1-15		17.14
June 16-30		13.34
July 1-15		2.74

Climate

Safflower is adapted to a Mediterranean type climate that provides moisture during the vegetative period of development and dry atmospheres during and after flowering. It is also adapted to a climate like much of India and Pakistan that provides: moisture during the summer prior to planting safflower; moderate temperatures during the winter when the safflower is growing vegetatively; and higher temperatures without rainfall during seed development, maturity, and harvest.

Time to maturity -- The minimum growing season for safflower is about 120 days, which prevails when the crop is grown in areas of high summer temperatures. In most areas where safflower is grown, temperatures during the first half of the plant's development are low to moderate and the growing season is 150 to 160 days.

The response of safflower to daylength has not been studied, but flowering does not appear to be inhibited when daylengths are over 12 hours.

Successful commercial safflower varieties have been early in maturity, most of them flowering within a week of the earliest possible type. A search of a large number of introductions has not uncovered varieties earlier than those commonly grown in India and Pakistan.

Temperature requirements -- Frost resistance depends upon the variety and stage of development. In the seedling stage, most varieties will tolerate temperatures down to -7° C., and some experimental types will withstand temperatures down to -12° C. Once stems have begun to develop, temperature of -4° C. will damage most varieties. In the bud stage or after flowering begins, any temperature below 0° C. will cause damage. If moisture is not deficient, safflower will tolerate temperatures above 38° C., but the upper limits have not been determined. Yields are generally higher when temperatures during flowering and immediately thereafter are on the moderate side (24° to 32° C.).

Atmospheric moisture -- High atmospheric humidities adversely affect safflower, mostly because they magnify the severity of foliar diseases. (See next section.)

Rain at harvest will germinate the seed in the head. This has been a problem in the Great Plains of the United States, in Queensland, Australia, and in very late plantings in California.

Susceptibility to Insects, Diseases and Other Pests

In general, safflower has been severely damaged by insects in the Old World, particularly where weedy relatives abound. On the other hand, insects have not been a particularly severe problem in areas where the crop has been recently introduced. Another general observation is that diseases are much more severe under irrigation or where high atmospheric humidities prevail.

Insects -- The most damaging insects of safflower is the safflower fly (*Acanthiophilus helianthi* Rossi), which is found in all areas of Asia, Europe, and Africa occupied by safflower and its wild relatives. It would appear to be less severe on early maturing materials, and very damaging on the latest materials. Larvae of the pest, if abundant, will destroy all the seeds in a head, often with little effect on the external appearance of the head. Tests of the USDA World Collection in Israel indicate that some varieties have more resistance than others.

Western flower thrips (*Frankliniella occidentallis* Perg.) cause early browning, bronzing, and blasting of buds in California. Some bud loss will occur if there are 20 to 25 nymphs per bud, and all buds will be destroyed if there are 150 nymphs per bud. Insecticides are recommended when 25 to 30 percent of the early buds are bronzed and blasted prior to the onset of bloom.

Another serious insect pest in California, particularly in late-sown fields, is lygus (*Lygus hesperus* Knight). If numbers of bugs and nymphs exceed 30 per sweep (1 per 8 or 9 buds), chemical control is recommended.

Other insects of more than minor importance that have been reported attacking safflower are:

In California: Green peach aphid (*Myzus persicae* Sulzer); black bean aphids (*Aphis fabae* Scop.); leaf curl plum aphid (*Aphis helichrysi* Kaltenback); onion thrips (*Thrips tabaci* Lind); and stem borer (*Melanagromyza virens* Loew).

In Northwest Mexico: green peach aphid; corn earworm (*Heliothis zea* Boddie); tobacco budworm (*Heliothis virescens* Fab.); tarnished plant bug (*Lygus lineolaris* Pal de Beauv.); beet armyworm (*Spodoptera exigua* Hub); cabbage looper (*Trichoplusia ni* Hub.); saltmarsh caterpillar (*Estigmene acrea* Drury); southern green stink bug (*Nezara viridula* L.); and brown stink bug (*Euschistus servus* Say).

In Spain: Armyworm (*Heliothis peltigera* Schiff); safflower fly; and the snout beetle (*Larinus flavesceus*).

In Israel: A detailed listing of insect pests of safflower in Israel is provided by Avidov and Kotter (1966).

Diseases -- Where irrigation is practiced, one disease that has been serious is Phythohthora root rot caused by *Phytophthora drechsleri* Tuck. Infected plants wilt, often rather quickly, turn light colored and die. Control is outlined above under water management. (See Page 46.)

Another root rot that is most severe in areas growing cotton is caused by *Verticillium albo-atrum* Reinke & Berthe. Affected plants first show interveinal and marginal chlorosis of lower leaves, followed by mottling and eventually yellowing of all leaves from the bottom to the top of the plant. The vascular tissue of the plant may be dark in color. Other susceptible crops are tomato, melons, potatoes, alfalfa, peaches, and olives.

A third root-rotting organism is *Fusarium oxysporum* f. *carthami* Klis. & Hous. A characteristic symptom is yellowing of one side of the plant or leaf.

Sclerotinia sclerotiorum (Lib.) d By. causes stem rot near the soil line with above-ground symptoms like those of Phytophthora root rot. Black sclerotia are present in the decayed stem pith near the soil line.

Rust caused by *Puccinia carthami* Cda. may attack plants in the seedling stage, causing girdling of the hypocotyl and death of the plant, sometimes several weeks later. At later stages, it forms dark brown pustules on cotyledons, leaves, and involucral bracts. This disease is distributed wherever safflower is

grown. Another rust caused by P. verruca Thuem. has been reported to occur in the Soviet Union and Israel.

Head blight caused by Botrytis cinerea Pers. is usually serious where humidities are high, as they are in coastal areas of California or in irrigated areas with frequent heavy dews. Affected heads turn light green and bleach out before the rest of the plant matures. Such heads are easily removed from the plant and contain partially developed seeds.

Also under conditions of high humidity, leaf spot caused by Alternaria carthami Chowd. may occur. Symptoms are large, brown spots on the leaves. It may kill seedlings in early stages. It has been a problem in the Great Plains area of the United States, in Northwest Mexico, and in Queensland, Australia.

Leaf spot caused by Cercospora carthami Sund. & Ramak. has been reported from India, Israel, and the Philippines when humidities are very high. Leaf spot caused by Ramularia carthamicola Darpoux is reported from France, India, Israel, Pakistan, and the Soviet Union.

Where rains occur in early stages, or sprinkler irrigation is used, bacterial blight caused by Pseudomonas syringae may occur. Symptoms are dark, water-soaked lesions on stems and leaf petioles, reddish-brown necrotic spots with pale margins on leaves, and severe necrosis of the terminal bud.

Cucumber mosaic causes a light- and dark-green mosaic pattern in the leaf, often accompanied by distortion of the leaf and stunting of the plant.

Parasites -- Broomrape (Orobanche spp.) has been seen attacking safflower in Egypt and Spain. Different levels of tolerance were observed in Spain, some experimental materials showing evidence of complete resistance. Dodder (Cuscuta spp.) has been found on safflower in California.

Special Harvesting, Storage and Processing

If combined directly, harvesting should be delayed until the moisture content of the seed is 8 percent or less. This will be when the seed of the latest heads has turned white in color.

Combine equipment is the same as that used for barley or wheat. Adjustments are as follows:

a) Reel speed about 25 percent faster than the forward speed of the combine;

b) Peripheral speed of the cylinder 750 to 900 meters/ minute, if harvested for oil, and 600 to 750 meters/ minute, if harvested for seed;

c) Clearance between cylinder bars and concave bars 1.0 to 1.5 cm.; and

d) Other adjustments set to remove only empty seed.

Safflower seed has a tough, resilient hull which resists damage during harvest. However, the embryo is extremely fragile and may suffer serious "invisible" damage, resulting in poor germination.

The crop may be windrowed when the seed contains 25 percent moisture, usually about 10 days before it would dry down to 8 percent. Four to 7 days later it may be combined using a pickup attachment.

For safe storage, the seed should contain no more than 8 percent moisture.

Conventional processing equipment used for other oilseed crops have been adapted for safflower. Both expeller and solvent equipment have been used, though usually combinations of both are preferred.

Often hulls are removed in part prior to processing, then are ground and blended back into the protein meal to adjust the latter to specified protein contents. If not blended into the meal, the disposal of the hulls presents a problem.

WEST PAKISTAN ENVIRONMENT AND CLIMATIC ANALOGS

The soils and climate of West Pakistan should be satisfactory for safflower production. Pests, including insects, birds, and weeds, will seriously affect production.

SOIL

Many soils of West Pakistan should be suitable for safflower. Shallow soils, sandy soils, and very heavy clay soils should be avoided.

WATER REGIME

Safflower will require irrigation since the average rainfall from monsoons is about 25 cm. It would be advisable to apply as much as possible prior to planting, perhaps in September.

Good water management will be required to avoid ponding of water, and to permit the soil to be waterlogged no more than 48 hours during an irrigation.

WEATHER

Over much of the lower elevations of West Pakistan, winter temperatures will not be low enough to affect safflower adversely When planted in October or early November, development will be completed by March, before the high summer temperatures occur.

Rainfall will be scarce or absent during almost the entire period of plant growth, preventing the occurrence, or reducing the severity, of several serious diseases of safflower such as Botrytis blight, Cercospora leaf spot, and Alternaria leaf spot.

INSECTS, DISEASES, AND OTHER PESTS

The safflower fly, the most serious pest of safflower, will be abundant in West Pakistan, particularly in areas where pohli (Carthamus oxyacantha) is a weed. Early-sown safflower probably will escape serious damage, but late-sown safflower or late-maturing varieties sown at an early date will be severely damaged. Damage is often not visible until the head is broken open shortly after flowering, when the larvae and/or pupae may be seen. If the heads are not examined and the plants are left to mature, low yields may be attributed to other causes. It is imperative that varieties and cultural operations be evaluated in reference to this pest.

Root rot diseases, including Phytophthora root rot, Verticillium wilt, Sclerotinia, and probably Fusarium wilt, will be problems. If Verticillium wilt occurs in cotton, it will also attack safflower with equal severity. It may even be necessary to avoid the use of safflower in a rotation containing cotton because of the susceptibility of present commercial varieties of safflower to this disease.

The high humidities of the lower Sind region, as a consequence of the proximity of the Arabian Sea, may increase the incidence of foliar diseases such as Cercospora leaf spot, Alternaria leaf spot, Botrytis blight, and rust.

Birds are a serious pest of many crops in West Pakistan, and safflower will be no exception. The danger of losses to birds will prohibit the use of spineless varieties, and may encourage the use of types with abundant and long spines. Very thin-hulled varieties will be damaged more severely than thick-hulled varieties, and this may impose limits on the degree to which oil content can be raised.

The related weed <u>pohli</u> will be a problem if it develops with cultivated safflower. However, <u>pohli</u> will be 3 to 4 weeks later in developing than early varieties of cultivated safflower, and may not adversely affect safflower yields. More serious will be the insects and diseases of <u>pohli</u> that will attack safflower. Fortunately, the oil of pohli is essentially the same as that of cultivated safflower, so admixtures of the seed of <u>pohli</u> in safflower seed will not adversely affect quality of the oil.

<u>Pohli</u> is widespread in northern portions of West Pakistan, being seen in 1958 from south and east of Lahore, north to Rawalpindi, and West to Peshawar. It was usually abundant in winter grain fields with little or no irrigation. Where irrigation was practiced on an intensive scale, this weed was less abundant or disappeared. It occurred on roadsides where it was present in adjacent fields. In undisturbed grasslands, <u>pohli</u> was not present.

In the Peshawar area, <u>pohli</u> in one field had many plants with "vegetative" and/or sterile heads present. In vegetative heads, the seeds elongated into a strap-like structure that was green in color. Because such plants occurred in colonies, it was thought that a virus spread by an insect may have been involved.

A second wild species, <u>C. turkestanicus</u> Popov (usually called <u>C. lanatus</u> L. in most herbaria), occurs in northern portions of West Pakistan, from Abbottabad to Peshawar. This species, with 32 pairs of chromosomes, is remotely related to cultivated safflower with 12 pairs.

AVAILABILITY OF ADAPTED GERM PLASM

In contrast to most safflower of India which was essentially devoid of yellow-flowered types, that in the Gujrat area of West Pakistan had several yellow-flowered plants present. It is suggested that introgression of yellow flowers from the wild <u>C. oxyacantha</u> to the domestic species has occurred at some date in the past, even though the flowering dates of the two species do not normally overlap.

Seed of cultivated safflower may be obtained from most shops selling herbs and plant extracts as medicines. Such shops are called <u>panseri</u>.

Under California conditions, collections from West Pakistan have not been too promising or useful as a source of genes. In this respect, they are similar to most collections from India. In general, they are early, strongly branched, shorter than introductions from other countries, strongly spined, and small headed. Oil contents have usually been below 30 percent.

YIELDS

Reliable yields from test plots of safflower were not available from West Pakistan. It is estimated that yields should be about two thirds of that obtained from wheat. With adequate soil nutrients and water, maximum yields of 4500 kg./ha. should be possible.

MULTIPLE CROPPING

Safflower will occupy the ground from October to March, about 150 days. Harvest should be completed well before the monsoon season starts. Summer crops might be sesame, peanuts, sorghum, millets, or rice.

AGRONOMIC AND ECONOMIC INTERACTIONS

This section will consider agronomic interactions only; economic interactions will require information on costs of production, selling prices of commodities, availability of transportation and processing, etc., which was not available.

OTHER CROPS

The winter cereals, wheat in particular, will be strongly competitive with safflower. Wheat will cost slightly less to produce because it will require less time on the land, less water, and may be easier to harvest. On the other hand, because safflower matures later than wheat, it will, in combination with wheat, permit a longer harvest season with better utilization of equipment and labor.

Wheat production will permit better control of pohli, the wild safflower, if herbicides are used at the proper time. On the other hand, the tolerance of safflower to trifluralin, EPTC, and chloro-IPC may permit better control of other weeds if safflower is used.

Cotton and safflower may not be possible in the same rotation because both are susceptible to Verticillium wilt (See Page 53).

Oil crops that could be used as summer (Kharif) crops with safflower are peanuts and sesame.

Since West Pakistan needs vegetable oils primarily for use in cooking, it is likely that high oleic safflower will be of more economic value than the usual high linoleic type (See Page 43).

It is expected that the cattle, goats, sheep, and water buffalo in West Pakistan could readily use all the meal produced from safflower. Being ruminants, they are not dependent upon the feed as a source of all essential amino acids (See Page 44).

Safflower should not be sown after safflower because of the possibility of disease increasing. However, it is not known whether or not rust spores survive on plant parts and in the soil through the warm Kharif season in West Pakistan as they do through the cool, wet winter in California.

OTHER USES OF WATER

Safflower will benefit from deep irrigations, providing the soil is permeable. In soils 3 to 4 meters deep, this will permit the storage of sufficient water to produce a safflower crop without the addition of supplemental water, realizing, however, that maximum yields cannot be achieved by this practice.

Safflower may have merit in areas with a high water table because of its ability to draw water from the soil zone above the water table. Properly managed, safflower may even lower the level of the water table.

OTHER USE OF MACHINERY OR LABOR

An important advantage of safflower is that it can be grown with the same equipment used for wheat. Only minor adjustments are required (See Page 51).

STATUS OF RESEARCH AND DEVELOPMENT

IN THE UNITED STATES

Research and development of safflower in the United States is centered in California and Arizona, where it is conducted by

both Department of Agriculture and university personnel. In addition, a strong program is carried forward by the USDA in Beltsville, Maryland. Utilization research is centered at the USDA Western Regional Research Laboratory at Albany, California. Variety development is conducted by plant breeders with commercial companies, USDA, and state experiment stations. Research and development is integrated by conferences of research workers held every 2 or 3 years.

There has been a steady increase in oil content from about 35 to 36 percent in N852 some 20 years ago to 42 to 43 percent in some commercial varieties presently grown. This has been achieved mostly by reducing hull content. Seed yield has not been changed appreciably, but oil yield per hectare has been increased. Possibilities for increases in oil content and changes in oil quality are discussed on pages 40 to 44.

A roster of research personnel devoting much of their research time to safflower is given below:

ARIZONA

- University of Arizona, Tucson, Arizona, 85721:

  Dr. D. D. Rubis, Development of varieties with high oil content and inbred lines for use in producing hybrid varieties; inheritance studies of various characters.

  Dr. L. H. Zimmerman (USDA), Genetics of resistance to, or tolerance of, environmental factors (e.g. cold and heat, day length, and high humidities at harvest) which adversely affect development or production.

  Dr. V. Jensen (USDA), Physiology of safflower.

- University of Arizona Field Station, P.O. Box 858, Mesa, Arizona 85201:

  Mr. G. H. Abel (USDA), Variety development; studies of yield components.

CALIFORNIA

- University of California, Davis, California 95616:

  Dr. P. F. Knowles, Germ plasm development; genetics of oil quality; cytogenetics and genetics of domestic and wild species.

Dr. J. M. Klisiewicz (USDA), Safflower diseases and their control.

Mr. E. C. Carlson, Safflower insects and their control.

- J. S. Cotton Research Station, Shafter, California 93263:

  Mr. L. Urie (USDA), Germ plasm and variety development.

  Mr. W. F. Peterson (USDA), Studies of cultural practices.

- USDA-ARS, Crops Research Division, Oilseed and Industrial Crops Research Branch, Beltsville, Maryland 20705:

  Dr. R. W. Howell, Head.

  Dr. C. A. Thomas, Diseases of safflowers and their control; germ plasm and variety development.

- USDA-ARS, Western Utilization Research and Development Division, 800 Buchanan Street, Albany, California 94710:

  Dr. G. O. Kohler, Safflower protein.

  Dr. G. Fuller, Safflower oil and protein.

  Dr. H. J. Burkhardt, Color of oil.

  Mr. J. Guggolz, Composition of seed and meal.

  Mr. R. G. Binder, Odor problems of oil and meal.

  Miss Rhoda Palter, Bitter principle of the meal.

- USDA Regional Plant Introduction Station, Washington State University, Johnson Hall 59, Pullman Washington 99163:

  Dr. A. M Davis, Quarantine and preservation of safflower introductions.

Plant breeders with commercial companies are as follows:

- Pacific Oilseeds, Inc., P. O. Box 1008, Woodland, California 95696:

Dr. C. E. Claassen.

Dr. D. L. Smith.

- Cargill, Inc., Route 1, Box 405, Dixon, California 95620:

  Mr. A. B. Hill.

- Cal West Seeds, Inc., P. O. Box 817, Woodland, California 95695:

  Dr. I. J. Johnson.

- Anderson, Clayton & Company, Industrial Division, P. O. Box 2988, Phoenix, Arizona 85036:

  Mr. D. G. Lorance.

- J. G. Boswell Company, P. O. Box 877, Corcoran, California 93212:

  Dr. W. Parkey.

IN PAKISTAN

West Pakistan undoubtedly has evaluated the local types available from East Pakistan. However, it is doubtful that any of these would be acceptable for commercial use, primarily because of their low oil content.

Types from East Pakistan will be of interest primarily because they frequently have high levels of oleic acid in the oil. Again, it is expected that they will be low in oil, an opinion based on analyses of introductions from the Dacca area.

Evidence currently available indicates that East Pakistan has not been explored adequately to determine the full range of types that are available. Of interest would be information on the local assessment of high oleic oil obtained from the safflower in the Dacca area. Close as the farmers are to their crops and products obtained therefrom, it would be surprising if they did not know the differences between high linoleic and high oleic safflower types.

Undoubtedly, U. S. varieties have been evaluated in several areas, judging by the number of seed samples of U. S. types introduced into West Pakistan. It is possible that the slightly later maturity of U. S. types would put them at some disadvantage with local types, and for the following three reasons: 1) early

maturing types, in the absence of supplemental irrigation water or where crop irrigations are infrequent, will have some advantages over later types; 2) early varieties may escape damage from the safflower fly and other insects; and 3) if stands are thin (the general rule in West Pakistan and India), the strongly branched local types will probably do better than introduced types with less branching.

Research on safflower in Pakistan should do the following:

1) Evaluate the World Collection of safflower in comparison with local types. Such evaluations should identify the characteristics which contribute to superior performance.

2) Selected typical and superior types from different areas of the world should be evaluated in different areas at different seeding dates, seeding rates, levels of fertilizer, and levels of irrigation.

3) Cross superior types from above research with leading U. S. varieties and select in segregating generations for superior genotypes. Evaluations should be made under the optimum cultural conditions available to farmers who possibly might grow safflower.

4) Evaluate carefully the materials of all this research for resistance to insects and diseases. Where resistance is found, it should be incorporated into breeding stocks.

5) Assess the potential of wild safflower (_C. oxyacantha_) as a source of useful genes. Extensive as the populations of this species are in West Pakistan, a diligent search should uncover genes for resistance to both insects and diseases. _C. oxyacantha_ might also be a source of genes which improve yield and the adaptation of cultivated safflower to the environment of West Pakistan. Because _pohli_ is closely related to cultivated safflower, the two species cross readily to produce fertile progeny; consequently, it will be no problem to transfer genes from the wild to the domestic species.

6) Utilization research should determine the relative merits of high linoleic and high oleic safflower oils for West Pakistan. It is likely that the high oleic type will be the most desirable type if the oil is used primarily in cooking.

ELSEWHERE

Research at the Centro de Investigaciones Agricolas del Noroeste at Ciudad Obregon, Sonora, Mexico, has shown the best cultural methods to use for safflower in irrigated areas of

Northwest Mexico. A recent publication titled "Cartamo" gives recommendations on date of seeding, soil preparation, seeding methods, fertilization, irrigation, weed control, insect and disease control, and harvesting methods.

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SESAME

SESAME 30/

WORLDWIDE PRODUCTION OF SESAME

INHERENT PRODUCTION POTENTIAL IN TERMS OF SEED, OIL, PROTEINS, AND OTHER PRODUCTS

Seed Yields

According to FAO, average seed yields of sesame in 1967 ranged from a low of 130 kg./ha. in the USSR to a high of 910 kg./ha. in Ecuador (Table 15). The highest average yields reported in the 1963-67 period never exceeded 1000 kg./ha. These yields, with very few exceptions, were obtained from shattering varieties of sesame, grown without irrigation and harvested by hand. Yields obtained in irrigated test plots in the United States and abroad are much higher and, on certain years and locations, reached 2700 kg./ha. Non-shattering varieties are not grown commercially. Reports from small scale tests in the United States indicate that the highest yields obtained under optimum conditions and irrigation have not exceeded 1350 kg./ha.

Oil Content

Analyses of over 1000 introductions included in the world collection of sesame varieties of the USDA and the University of California indicated that oil content varies from 41 to 60 percent and iodine values from 104 to 130.

Protein Content

Protein content of the seed of over 100 selections made in California ranged from 26 to 30 percent. Protein content of the meal (8 percent moisture and 1 percent oil basis) varied from 48 to 59 percent. Protein availability in flower from sesame meal was 95 percent.

QUALITY OF OIL AND PROTEIN, AND POTENTIAL USES

The fatty acid composition of the oil in the above mentioned world collection of sesame varieties had the following range:

30/ D. M. Yermanos, University of California, Davis, prepared this section on Sesame.

Table 15.--World production of sesame.

Area = 1000 Hectares
Production = 100 Metric Tons
Yield = 100 kg./Hectare

Continent & Country	1948-1952	1952-1956	1963	1964	1965	1966	1967
Europe							
Bulgaria							
Area	3	3	2	2	-	4	6
Prod.	11	10	3	3	-	6	13
Yield	3.5	3.3	1.2	1.3	1.1	1.5	2.2
Greece							
Area	33	32	30	22	12	16	14
Prod.	92	113	112	77	43	57	56
Yield	2.8	3.5	3.7	3.5	3.6	3.5	4.1
Italy							
Area	1	1	2	2	2	2	2
Prod.	4	7	12	11	11	12	12
Yield	5.9	6.5	7.1	6.8	6.6	7.0	6.8
Yugoslavia							
Area	2	1	2	2	1	1	1
Prod.	7	4	10	6	3	3	4
Yield	3.0	2.6	4.4	3.5	2.7	3.8	5.0
U.S.S.R.							
Area	40	27	3	1	1	1	1
Prod.	40	28	2	1	1	-	1
Yield	1.0	1.0	.6	.9	.7	.4	1.3
N. & C. America							
Costa Rica							
Area	-	1	-	-	-	-	-
Prod.	2	2	1	1	1	1	1
Yield	7.8	4.0	5.3	4.2	5.3	5.3	5.3
Dominic Rep.							
Area	1	1	1	1	1	1	1
Prod.	5	5	3	3	3	3	3
Yield	5.0	5.1	5.0	5.1	5.8	5.8	5.8

--Continued--

Continent & Country	1948-1952	1952-1956	1963	1964	1965	1966	1967
El Salvador							
Area	6	3	2	2	2	2	2
Prod.	44	33	10	7	8	8	8
Yield	7.9	9.6	5.0	3.5	4.0	4.0	4.0
Guatemala							
Area	1	1	2	3	4	5	5
Prod.	6	5	10	15	21	33	33
Yield	5.1	5.4	5.9	6.0	6.0	7.0	7.0
Honduras							
Area	1	1	1	1	1	1	1
Prod.	4	4	5	5	5	5	5
Yield	7.0	7.1	7.2	7.7	7.1	7.1	7.1
Mexico							
Area	159	176	251	261	273	281	285
Prod.	801	921	1693	1717	1620	1761	1796
Yield	5.0	5.2	6.8	6.6	5.9	6.3	6.3
Nicaragua							
Area	21	18	7	9	8	9	9
Prod.	119	96	47	58	53	60	60
Yield	5.6	5.4	6.7	6.7	6.6	6.7	6.7
U.S.A.							
Area	...	1	1	1	1	1	1
Prod.	...	7	6	4	4	4	4
Yield	...	5.5	5.5	5.3	5.3	5.3	5.3
<u>S. America</u>							
Brazil							
Area	9	7	7	7	7	7	7
Prod.	44	38	40	40	40	40	40
Yield	5.0	5.2	5.7	5.7	5.7	5.7	5.7
Colombia							
Area	15	17	70	117	121	115	80
Prod.	71	54	350	491	715	620	400
Yield	4.8	3.2	5.0	4.2	5.9	5.4	5.0

--Continued--

Continent & Country	1948-1952	1952-1956	1963	1964	1965	1966	1967
Ecuador							
Area	-	-	1	1	2	3	2
Prod.	-	-	6	9	18	23	11
Yield	-	-	10.0	9.6	7.5	9.1	6.8
Peru							
Area	-	-	-	-	-	-	-
Prod.	1	1	2	2	2	2	2
Yield	4.5	5.9	6.3	6.3	6.3	6.3	6.3
Venezuela							
Area	8	11	61	68	87	95	133
Prod.	68	77	309	466	541	600	805
Yield	8.8	6.8	5.0	6.8	6.2	6.3	6.0
<u>Asia</u>							
Burma							
Area	371	408	383	703	479	478	500
Prod.	437	473	538	1004	622	566	833
Yield	1.2	1.2	1.4	1.4	1.3	1.2	1.7
Cambodia							
Area	3	5	19	15	12	15	8
Prod.	11	18	123	100	80	98	49
Yield	4.1	3.4	6.5	6.7	6.7	6.7	6.5
Ceylon							
Area	12	15	17	15	15	10	11
Prod.	40	54	74	74	67	49	59
Yield	3.3	3.5	4.3	4.8	4.4	4.7	5.5
China Taiwan							
Area	5	5	7	5	6	6	6
Prod.	18	21	25	23	29	18	34
Yield	3.4	4.0	3.7	4.4	5.3	3.0	5.6
Cyprus							
Area	2	1	1	1	-	-	-
Prod.	3	2	1	1	1	1	1
Yield	1.4	1.5	2.2	1.0	1.8	1.9	1.9

--Continued--

Continent & Country	1948-1952	1952-1956	1963	1964	1965	1966	1967
India							
Area	2182	2408	2412	2513	2480	2793	2687
Prod.	4294	5084	4390	4928	4247	4160	4214
Yield	2.0	2.1	1.8	2.0	1.7	1.5	1.6
Indonesia							
Area	10	10	...	10	...	...	...
Prod.	20	20	...	20	...	...	...
Yield	2.0	2.0	...	2.0	...	...	...
Iran							
Area	11	12	7	7	7	7	7
Prod.	89	99	61	61	61	61	61
Yield	8.5	8.5	8.5	8.5	8.5	8.5	8.5
Iraq							
Area	26	23	10	13	15	16	17
Prod.	94	139	61	78	95	109	120
Yield	3.6	6.0	6.0	6.2	6.5	7.0	7.0
Israel							
Area	1	2	3	3	1	1	1
Prod.	5	6	14	16	5	5	7
Yield	3.4	3.9	4.7	5.9	4.2	4.2	5.2
Japan							
Area	7	10	7	7	6	6	5
Prod.	46	57	47	43	38	34	30
Yield	6.4	5.9	6.6	6.4	6.3	6.2	6.0
Jordan							
Area	6	14	5	4	4	2	2
Prod.	17	40	17	17	14	8	8
Yield	2.8	2.8	3.8	4.7	4.0	3.6	3.6
Korea Rep.							
Area	5	5	8	9	10	11	13
Prod.	17	18	30	38	42	52	61
Yield	3.4	3.3	3.9	4.2	4.1	4.6	4.6
Lebanon							
Area	2	2	-	-	-	-	-
Prod.	12	14	4	1	2	2	1
Yield	7.5	9.2	9.0	9.3	10.0	10.0	7.5

--Continued--

Continent & Country	1948-1952	1952-1956	1963	1964	1965	1966	1967
Pakistan							
Area	78	86	79	85	79	81	84
Prod.	329	362	335	315	315	343	394
Yield	4.2	4.2	4.2	3.7	4.0	4.3	4.7
Saudi Arabia							
Area	1	2	1	-	1	1	1
Prod.	3	11	4	3	4	4	4
Yield	4.6	6.0	6.5	7.5	7.2	7.2	7.2
Sth Yemen							
Area	3	3	1	2	2	2	2
Prod.	8	11	9	9	9	10	10
Yield	2.5	4.4	7.5	5.6	5.6	5.8	5.9
Syria							
Area	14	25	7	10	7	6	...
Prod.	83	139	53	65	49	57	...
Yield	6.0	5.6	7.1	6.8	7.1	8.9	...
Thailand							
Area	16	16	17	16	25	25	24
Prod.	81	104	160	130	180	180	170
Yield	5.2	6.5	9.2	8.0	7.3	7.3	7.1
Vietnam NTH							
Area	5	5	6	7	7	7	7
Prod.	20	21	24	29	30	30	30
Yield	4.0	4.0	4.0	4.1	4.2	4.2	4.2
Vietnam Rep.							
Area	1	2	2	1	1	-	1
Prod.	4	7	10	4	3	2	3
Yield	3.7	4.5	4.0	4.8	3.7	4.5	5.1

palmitic acid	-	from 7 to 11 percent
stearic acid	-	from 2 to 6 percent
oleic acid	-	from 32 to 54 percent
linoleic acid	-	from 39 to 56 percent

Other fatty acids present in small quantities (less than 1 percent each) are myristic, arachidic, and hexadecenoic.

Sesame is a high quality oil and is used as any other vegetable oil in cooking and salads and also in the preparation of various confectionery products. Because of its stability, it is sometimes used in blends with other vegetable oils, to which it confers higher stability. Sesame oil could be used in several industrial applications in the same way as safflower or corn oil. Its high price, however, makes such uses unprofitable. The wholesale price of refined sesame oil in New York in the period 1964-68 ranged from 33 to 39 cents per pound; the corresponding range for safflower oil was 14.1-15.4 cents, cottonseed oil 13-17 cents, corn oil 13.7-19.2 cents, and soybean oil 10.2-13.5 cents.

Average amino acid composition of decorticated sesame seed reported in the literature is as follows (grams of amino acid per 16 grams of nitrogen):

Arginine	8.1
Lysine	2.7
Histidine	1.5
Aspartic acid	7.4
Glycine	6.8
Serine	4.1
Glutamic acid	15.5

Total amino acid composition of lipid free California-grown sesame meal is as follows (percent by weight):

Lysine	1.41
Histidine	1.04
Ammonia	.33
Arginine	5.96
Aspartic Acid	3.94
Threonine	1.76
Serine	2.16
Glutamic Acid	9.36
Proline	1.38
Glycine	2.42
Alanine	2.15
Half Cystine	.57
Valine	2.24
Methionine	1.56
Isoleucine	1.85
Leucine	3.15
Tyrosine	1.56
Phenylalanine	2.05

The chemical composition of seed and meal of sesame grown in India has been reported as follows:

Table 16.--Composition of seed and meal of sesame grown in India.

Constituent	Seed		Meal			
			Expeller Pressed		Hexane Extracted	
	Whole	Decorticated	Whole	Decorticated	Whole	Decorticated
	Percent of total weight					
Moisture	5.4	6.2	8.1	8.3	8.6	8.8
Fat (ether extract)	50.2	54.1	13.5	12.7	0.8	1.1
Protein (N x 6.25)	19.8	21.1	35.1	41.3	39.6	46.7
Mineral matter	4.8	2.3	8.9	4.8	9.7	5.2
Crude fiber	3.2	1.4	5.3	3.1	6.1	3.2
Oxalic acid	1.72	0.2	3.01	0.41	3.6	0.46
Carbohydrates	14.88	14.7	26.09	29.39	31.6	34.54
Calcium (ca)	1.06	0.19	1.78	0.38	2.14	0.45
Phosphorus (P)	0.47	0.48	0.81	0.99	0.97	1.16

Seed coat in most varieties ranges between 10-12 percent of the whole seed. In the so-called "rough seed coat" varieties, it may be as high as 17 percent.

Sesame is deficient in lysine but rich in methionine. The lysine requirement set by FAO is 4.2 grams per 16 grams of nitrogen; sesame meal has 2-3 grams. Similarly, the requirement for methionine is 2.2 grams; sesame has 3-4 grams. Meals from all other major seed oils are deficient in methionine; e.g., cottonseed has .9-1.2 grams , peanuts .8-1.4 grams, safflower .4-1.1 grams, sunflower 1.3-1.9 grams, and soybeans 1.0-1.1 grams.

Sesame grown in India was evaluated as a source of amino acids in comparison with peanuts, soybeans, and whole egg. The following results were obtained:

Table 17.--Amino acid composition of the proteins of black and white varieties of sesame seed as compared with the proteins of certain other oilseeds and whole egg.

Amino acid	Sesame		Literature values	Groundnut	Soybean	Whole egg
	Black	White				
	Grams per 16 grams of nitrogen					
Arginine	12.5	11.8	8.7	11.3	7.3	6.2
Histidine	2.14	2.4	1.5	2.1	2.9	2.1
Lysine	2.9	3.5	2.8	3.0	6.8	6.3
Tryptophan	1.3	1.6	1.8	1.0	1.4	1.5
Phen lanine	6.2	6.3	8.0	5.1	5.3	5.7
Methionine	3.3	3.8	3.2	1.0	1.7	3.2
Leucine	8.9	7.4	7.5	6.7	8.0	9.0
Iso leucine	3.9	3.7	4.8	4.6	6.0	6.2
Valine	3.5	3.6	5.1	4.4	5.3	7.0
Threonine	3.6	3.9	4.0	1.6	3.9	4.9

Proteins of a blend of groundnut, soybean, and garbanzo beans had a protein efficiency ratio of 1.7. Addition of sesame flour to the protein increased the protein efficiency ratio to 2.1, which compares favorably with a value of 2.55 obtained for proteins of skim milk powder. Sesame does not contain the trypsin inhibitor.

Sesame cake may be processed for the isolation of its protein. The cake residue left after the extraction of protein can still be used as a cattle feed supplement because the growth promoting substances present are carried over to the final hydrolysate without any impairment to the biological value of sesame protein.

Sesame is a good source of calcium. Sesame ash contains:

K_2O	11.9 percent	Fe_2O_3	3.0 percent
Na_2O	1.8 percent	P_2O_5	30.8 percent
CaO	35.1 percent	SO_3	.9 percent
MgO	12.9 percent	Cl	.2 percent

Several steroids have been found in sesame oil. Sesame meal is low in vitamin A but is similar to soybean and cottonseed meals in riboflavin content (0.4 mg. percent). Also, it contains .8 mg. percent pantothenic acid, 4.4 mg. percent niacin, and 140 mg. percent of choline.

Sesame oil was found to increase the insecticidal potency of pyrethrums. Investigations on the synergistic activity of the oil led to the discovery of two of its minor constituents, sesamin and sesamolin. Thirty-three strains of sesame seed grown in Texas were found to have 0.34-1.13 percent sesamin and 0.13-0.58 percent sesamolin. A third important minor compound of sesame seed is sesamol, which is a strong antioxidant, giving sesame oil its outstanding keeping qualities. Sesamol occurs in the oil in its free form, but it is also liberated from sesamolin by dilute mineral acids or by hydrogenation. The stability of sesame oil after hydrogenation has been attributed to the liberation of sesamol from sesamolin. Tests in different locations indicate that this factor does not affect significantly the sesamin and sesamolin content of sesame oil. Both of these compounds, however, were drastically reduced in seed which was damaged by frost.

The above discussion of the composition and qualities of sesame seed, meal, oil, and minor components underlines the value of these products in human nutrition. In addition to sesame oil being a high quality edible oil, sesame meal can be used, as such, in high protein bakery products or as an enriching agent with flour, meat, and vegetables for the production of various foods, including baby formulas, breakfast cereals, potato chips, etc.

Recently, the discovery that the green sesame plant is a good source of protein may open up new uses of this crop. Dry sesame leaves contain 20-29 percent protein, and stems 4-11 percent. Yield of dry leaves per hectare was as high as 1.4 tons, and total protein produced per hectare from stems and leaves reached half a ton.

Sometimes sesame is grown as an ornamental because of its attractive foliage and flowers. Bees work the sesame flowers, especially when other flowers are scarce in the summer. Shattering varieties of sesame in some cases are grown to provide food for and to attract game birds.

GROWTH CHARACTERISTICS

Soil Requirements

Sesame does well in a variety of soils, but it performs best on well drained, fertile soils of medium texture and neutral reaction. Shallow soils with impervious layers which cause irrigation or rain water to stand in the field for more than 24 hours should be avoided.

At the seedling stage, sesame is quite sensitive to salinity; at later stages of development, it is considered about as tolerant to salinity as barley. Preliminary information from research currently in progress indicates that sesame is highly sensitive to sodium chloride salts and tolerant to sodium sulphide salts. Nitrogen fertilization appears to enhance salt tolerance of sesame.

Sesame is not considered a soil building crop, yet it is not "hard" on the land either. Under current practices of harvesting, only the seed is removed from a field, while the remainder of the plant is returned to the soil.

Sesame does not respond to fertilization as much as some other agronomic crops (e.g. corn) and, therefore, many fertilization trials have been inconclusive. However, fertilization trials in South America point to the need of different fertilizer applications for maximum yields, depending on the region where the crop is grown. Thus, in one location a yield of 920 kg./ha. was obtained with 390 kg./ha. of 10-16-0 (unfertilized check: 380 kg./ha.); in another, 900 kg./ha. was obtained with 460 kg./ha. of 10-16-6 (check 450 kg./ha.); and in a third location, 750 kg./ha. was obtained with 500 kg./ha. of 10-15-10 (check: 480 kg./ha.).

Water Requirements

Sesame is generally considered as a drought resistant crop. It is safe to say that sesame can be grown profitably without irrigation where dryland sorghum or cotton are grown profitably. Highest sesame yields are obtained under irrigation. However, sesame is not tolerant to excessive soil moisture and yields are sharply reduced by water standing in a sesame field for more than a few hours. Successive cycles of drought and excessive soil moisture seem to favor the appearance of root and stem rot. In Southern California, 400-500 mm. of irrigation water are needed for highest sesame yields. Excessive moisture at planting time, when accompanied by low temperatures, favors the appearance of seedling diseases which may result in complete loss of stands. Excessive rainfall and high atmospheric humidity promote the incidence of phytopathological diseases, causing serious yield reductions.

Time to Maturity

Sesame tends to perform best in areas where temperatures remain high during the entire growing season. With few exceptions, sesame seed will not germinate at a constant temperature of 20° C. or lower. Plant development is retarded by cool temperature, even if the cool temperatures occur at night only. In general, sesame should not be planted until over a month after the last killing frost, and the harvest should be completed before any danger of frost in the fall. As a rule of thumb, sesame should have a minimum of 5 frost-free months. Under dry land conditions, fruiting may slow down when maximum temperatures exceed 40° C. With adequate soil moisture, however, sesame will stand a maximum of 50° C. without any apparent injury.

Most of the varieties developed in the U.S.A. require 90-120 days from planting to maturity. Non-shattering varieties are later maturing than shattering ones and require a longer time to dry, after they are cut, before they can be threshed efficiently. There are shattering varieties, however, grown in Central America and Africa which have a short life cycle of about 75 days.

Most of the sesame varieties respond to photoperiod very strongly. Thus, varieties adapted to latitudes close to the equator, when planted in latitudes between 30° and 40°, grow about 50 percent taller, blossom later in the summer, and produce very little seed. On the contrary, varieties adapted to latitudes of 30°-40° grow to half their normal height when sown close to the equator and produce very little seed. A few varieties are available which respond weakly to daylight and often produce acceptable yields at latitudes other than the ones they were developed in.

Susceptibility to Diseases and Insects

Diseases -- Diseases of sesame include the following:

- Seedling Diseases -- Sesame is very susceptible to root rots and damping off diseases caused by phycomycetes. These fungi affect subterranean portions of the seedling at first and often advance above ground and produce rapid killing, especially under high soil moisture and cool temperature.

Sesame seed must be treated before planting with a seed protectant; most commonly used chemicals include: Spergon (4 ounces per 100 lbs. of seed); Captan or Orthocide 75 (2 ounces per 100 lbs. of seed); Demosan-Du Pont or Terra-Coat L21-Olin (4-8 ounces per 100 lbs. of seed); and Arasan or Thiram 75W (2-3 ounces per 100 lbs. of seed. Seed treatments containing sulfur compounds should be avoided; when excessive amounts of the latter are used,

the seedlings may be badly distorted and stunted. It is advisable to treat seeds before germination tests are conducted since mold growth is so rapid on seeds in the germinator that accurate counts of germinated seed may not be possible. Seed treatment is especially important with non-shattering varieties, which usually require 2-5 additional days to emerge and need longer protection from soil borne seedling diseases.

• Bacterial Leaf Spot (Pseudomonas sesami Malkoff) -- The disease has been reported from Greece, India, Yugoslavia, Africa, and Brazil, and occurs in most areas where sesame is cultivated.

The bacterium is a short and thin (2.7 by 0.8 micron), hyaline, weakly motile, non-sporiferous, gram-negative rod with rounded ends and one or several polar flagella. On potato agar, it forms greyish-white, transparent, rounded, flat colonies, not discoloring the substratum. The optimum and maximum temperatures for growth are 25° to 35° C., and the thermal death point is about 49° C. The optimum acidity is between 15° and 18° C. of Fuller's scale, with a maximum at 30° C. and a minimum at -15° C. The bacterium is highly resistant to desiccation and freezing, and cultures retained their viability and pathogenicity after 10 months.

Symptoms of the diseases appear as small, watersoaked or oily, brown to blackish spots, 1-10 mm. in diameter, sometimes on the lower leaves but often on all parts of the plant that are above ground. These spots frequently coalesce to form larger areas which may be several cm. long. On the leaves, these large areas are delineated by the veins and, therefore, have an angular appearance. If the disease develops in the capsules, they turn black. Serious infections result in defoliation and death of the plant. The disease may appear in an epidemic form if moisture conditions are favorable and may cause very great losses. In high humidity, a drop of exude full of bacteria may appear on the under side of leaf spots.

The greatest susceptibility seems to be at the stage of the first pair of secondary leaves. Inoculation with bacteria at this stage produces lesions up to 2 mm., with star-like borders on the leaves. From these spots, the bacteria developed further along the veins, which are sooty in color, and make net-like forms on the attached leaf area. The infected leaves eventually curl and die.

Several approaches have been made to the problem of controlling Pseudomonas sesami. Streptomycin in solutions of 250 to 500 p.p.m., when used as a seed soak for 30 minutes, was able to eradicate the disease from infected seeds.

• Bacterial Leaf Spot (Xanthomonas sesami) -- The symptoms are similar to those produced by Pseudomonas sesami: small, dark olive-green spots first appear on the leaves and increase in size until they are about 2-3 mm. in diameter; then they become black in color and may coalesce. The infected tissue gradually becomes necrotic. The disease may spread in the stems and capsules, wher dark red-brown, raised lesions appear.

Xanthomonas sesami is a monotrichos species with a singl flagella at one pole, whereas Pseudomonas sesami is lophotrichos. It is a motile, Gram-negative, capsulated rod, .5 x 1.1 microns in size.

The disease is seed-borne; it can be eradicated from infected seeds by soaking them in hot water at 52° C. for 10 minutes or by treating them with a solution of Agrimycin-100 31/ (0.025 percent) and Wettable Ceresan (0.05 percent) for 6 hours.

• Phyllody Disease -- Phyllody manifests itself in the flowering stage by a transformation of the floral parts into green leaf-like structures, accompanied by excessive vegetative growth. The sepals become leafy, but remain small; the corolla and stamens become green. The filaments are flattened and have a tendency toward leafiness; the anthers become green and indehiscent, and lack functional pollen grains. The ovary becomes large and flat, with a soft texture and wrinkled surface; in some cases, two separate leaf-like structures develop in its place. The ovules are replace by small leaf-like shoots, which grow through the margins of the joined carpels. From these shoots grow more leaves and phylloid flowers, giving the impression that the pedicel has grown through the flower. Infected flowers have elongated pedicels and exhibit an actinomorphic symmetry in contrast to healthy flowers, which are zygomorphic. The veins of the infected calyx become thick and prominent. Because of smaller leaves, shortened internodes, and telescoped shoots, the diseased plants have bunchy tops; also, they are partially or completely sterile.

The best method for controlling phyllody is the eradication of the vectors spreading the disease (i.e., the Jassid fly).

• Alternaria Blight (Alternaria sesami Kawamura) -- Alternaria sesame has a widespread distribution and is often responsible for severe damage to sesame plants. The disease symptoms appear mainly on the leaf blade as brown, round to irregular spots varying from 1 to 8 mm. in diameter. In severe cases, many spots coalesce and affect major portions of the leaf. The fungus

31/ This and other pesticides mentioned in this report, except for Captan and Thiran, are not registered for use on sesame in the United States. Because of the limited production of sesame in the U.S., there is little economic incentive to obtain and maintain registration for uses on sesame.

attacks seedlings, stems of young plants, leaves, capsules, and often penetrates into the seed coat, where it remains viable for long periods of time. Thus, it moves with infected seed from place to place and perpetuates itself from one generation to the next. In severe attacks, seedlings are defoliated and, occasionally, killed by the disease.

Laboratory testing of seed samples from various countries indicated the presence of Alternaria sesami in India, China, Turkey, Venezuela, Iraq, Iran, Somaliland, Afghanistan, Argentina, Mozambique, Sudan, Greece, West Pakistan, and Israel, and certain other countries of South America.

The amount of damage to the sesame crop is dependent on the stage of growth and environmental conditions at the time of attack. Heavy rainfall and high humidity favor the development of the disease.

A. sesami, once it has penetrated the seed coat, is difficult to completely eradicate with chemicals, although seed treatments do reduce the number of spores in them. Seed treatment with Orthocide 75, Arasan 75 (75 percent thiram), and the antibiotic rimocidin gave good control of A. sesami in the seedling stage, and delayed infection until after flowering of the plant. Streptomycin and Spergon are ineffective. While seed treatment is able to improve development, treatments are ineffective if conditions are severe.

• Phytophthora Blight of Sesame (Phytophthora parasitica Dastur) -- Two species of the genus Phytophthora have been found to attack sesame: P. parasitica var. sesami Prasad and P. cactorum.

The disease is characterized by water-soaked lesions on leaves. The leaves are brown at first, then turn black; as the lesions grow larger they finally destroy the infected leaves. Lesions appear on stems also, usually close to the crown. Infected capsules are poorly formed and produce shriveled seeds, often brown in color. Under high atmospheric humidity, the capsules develop a woolly growth having caenocytic mycelia with papillate zoosporangia.

The disease has a higher severity in humid areas, but this is due to favorable moisture and temperature conditions rather than to the presence of virulent strains. The mycelium is caenocytic and highly branched in young cultures: septa can be seen when the cultures are 2 months old. Hyphae are 2-8 microns thick and hyaline. Under high humidity in field conditions, infected capsules have sporangia on a woolly mycelium. The sporangiophores, branched sympodially, are of the same thickness as the mycelium, have terminal sporangia, 33 x 38.5 μ in size, and a apical papilla; zoospores in sporangia are separated from one

another; oospores are spherical, smooth, double-walled, and hyaline.

The mycelium lives in the seed in a dormant condition, and the seed could cause the spread of the disease to new localities.

• Leaf Spot (Cercospora sesami Zimm.) -- Leaf spot caused by Cercospora has been reported in Uganda, Ceylon, Venezuela, Brazil, U.S.A., and Nicaragua. Losses due to the disease have not been assessed; a 5 percent loss in yield was reported from Assam in 1945.

The disease manifests itself before flowering time, and the first symptoms are the appearance of small light brown spots on both surfaces of the leaves. At first, these spots are roundish, but later coalesce to form irregular patches 5-15 mm. in diameter. As plants approach maturity, the color of the spots turns darker because of the formation of conidiophores and conidia. The number of spots may vary from 100 to 400 per leaf when humidity is high, and plants may become defoliated. Spots are also formed on stems and petioles -- light brown at first, dark brown later -- but the severity of infection there is lighter.

The mycelium of the fungus inside the host tissue is irregular septate, light brown and thick-walled. The conidiophores are produced in clusters of 5 to 10 each, and emerge through the stomata.

Disease is carried over through the seed, internally or externally, and through plant debris in the field. The superficial infection of seed could be completely eliminated by one year storage of the infected seed; the fungus, however, persists inside the grain. Hot water treatment (immersion of seed in water at 53° C. for 1 hour) has given encouraging results in disinfecting seed.

In addition, the following diseases have been recorded on Sesamum and require to be fully investigated, as some of these may assume serious proportions when the environmental conditions become favorable and possibly with the introduction of new varieties.

Leaf spots Alternaria sesamicola Kawamura-Hansford, 1931, Dey, 1948; A. solani (Ellis and Ever.) Jones and Grout-Mendez, 1940; Alternaria sp.-Litzenberger and Stevenson, 1957, Kvashnina, 1928; Corynespora cassicola (Berk. & Curt.) Wei-Mohanty and Mohanty, 1955; Phyllosticta sesami Bohovik-Bohovik, 1936; Macrosporium sesami Sawada-Kawamura, 1931, Bohovik, l.c.; Cladosporium sp. and Macrosporium sp.-Mitter and Tandon, 1930; Cylindrosporium sesami Hansford-Hansford, 1938 ; leaf blotch or aerial stem rot (Helminthosporium sesami-Parisi, 1933, Méndez,

1940, Watanabe, 1941, and Poole, 1956; H. gigasporum sub-sp. javanicum-Wallace, 1933); powdery mildews Leveillula taurica (Lèv.) Arn.[=Oidiopsis taurica (Lèv.) Salm.]-Patel, Kamat and Bhide, 1949; Sphaerotheca fuliginea (Schlecht.) Pollacci-Wallace, 1933, Lawrence, 1951; Oidium erysiphoides (Erysiphe polygoni D.C.). -Ciccarone 1940; Oidium sp. -Mehta, 1951, Uozumi and Yoshii, 1952); root rot [Fusarium coeruleum (Lib.) Sacc.-Prasad, 1944]; Foot rot [Fusarium solani (Mart.) App. and Wollenw.-Bremer et al., 1952], wilt (Verticillium dahliae Kleb.-Vassilieff, 1933, Hansford, 1939); Synchytrium diseases (Synchytrium sesami Sinha and Gupta-Gupta and Sinha, 1951; Synchytrium sesamicola Lacy-Lacy, 1951); white silk disease Hypochnus centrifugus (=Corticium centrifugum-Yogoki, 1927), Oospora sp.-Wallace, 1933; Phoma sp.-Luthra, 1934.

Insect Pests -- the major insect pests are as follows:

• Leaf Roller (Antigastra catalaunalis Duponchel) -- In the caterpillar stage, Antigastra is greenish with tubercles, feeds on tender leaves, webs their tops, and bores into the shoots and capsules. It has been estimated that a single caterpillar can destroy 2-3 sesame plants in a week.

The eggs are laid on the tender parts of the plant and have a 2-7 day incubation period, depending on the season. The larval stage has five instars lasting 10-33 days; the chrysalis is probably in the soil and lasts 4 to 19 days. The female moth lays from 86 to 232 eggs during the entire oviposition period, and there are approximately 14 generations per year.

The caterpillar is kept under control by a larval endoparasite, Cremastus flarooritìtalis Cameren. In South Africa, a small wasp belonging to the family Braconidae parasitizes the caterpillar.

Dusting the sesame plant with calcium arsenate and lime, DDT, methyldemeton, or parathion is effective in controlling the pest.

• Sesame sphinx (Acherontia styx Westwood) -- This is usually a minor pest and only when the pest population becomes very high does it appear to cause some damage. The larvae feed on the leaves, and sometimes the entire plant is defoliated.

This female moth lays its eggs singly on the leaves of the host plant. The eggs hatch in 2-5 days in April or May. The larvae are pale yellow and start feeding on the leaves soon after they hatch. The full grown (100 x 15mm.) larva is greenish with a hard integument, which has green oblique stripes on its sides, and with a characteristic curved horn on the dorsum of the caudal segment. The larval period lasts 2-3 weeks during the summer; the pest passes the winter in the pupal stage in the soil. Because

of this, ploughing to expose the underground pupae is recommended.

• Sesame Gall-fly (Asphondylia sesami, Felt) -- This pest occurs mostly in India. The female fly lays its eggs on the young floral buds. The maggots which hatch feed on the young flower parts. The injury resulting from this feeding causes the formation of abnormal gall-like buds. These buds do not develop into capsules and usually wither and drop off.

In addition to the above major insect pests, there are minor ones whose importance has not been verified. These are:

• Aphanus sordidus F (Lygaeidae:Hemiptera) -- This pod-sucking bug is about one-third of an inch long and dull brown to dark grey in color. The adults and nymphs infest tender pods and feed on the succulent juice. The alternate host plant for the pest is groundnut. Whitish eggs are laid singly in the soil. The newly hatched nymphs are pink. It takes about seven weeks to complete one life cycle. The control measure giving the most encouraging result has been 5 percent BHC dusting. The adults also have a habit of hiding in rubbish heaps of semi-dry leaves, so advantage could be taken of this habit by spreading some leaf rubbish near the plants and then destroying it when the pest infests it.

• Eusarcoccoris ventralis W. (Pentatomidae:Hymiptera) Nysious inconspicuous D. (Lygaeidae:Hemiptera) -- These two bugs are also known to attack sesame often, and destroy the tender pods and shoots by sucking the juice. Though the chemical methods of control have not been worked out to control these occasional pests, the usual mechanical methods of control, like use of nets and sticky boards, will be found effective.

Harvesting, Storage, Processing

Harvesting is the most difficult problem in sesame culture. Three approaches have been attempted for a satisfactory solution, based on the genetic materials available:

Shattering Varieties -- Sesame is harvested when flowering has stopped and most of the leaves have dropped off. At this stage, the plants may still look green or yellowish. Cutting is done by hand or mechanically. Hand cutting is the most efficient method and no seed is lost in the field because all plants point in the same direction in the tied bundle. The bundles are shocked and left to dry for 2-3 weeks; 4-6 bundles are placed in each shock when tall varieties are grown, or up to 400 bundles with short material. The cost of cutting, however, or the inavailability of labor may be limiting factors.

Machinery available for sesame cutting is not very suitable for this operation. Most of the machinery tried has been designed for other crops and not for sesame. Thus, the standard grain binder does not make good bundles because the plants get to the attachment which ties the bundle oriented in different directions. Although large areas can be cut and bundled this way, the practice has not been followed because of high seed losses at the time the bundles dry in shocks. A different type of self-propelled binder is available in Italy (Laverda Co., Bertolini Co.) which keeps the cut sesame upright and drops the bundle between the drive wheels of the forward moving machine. These binders have a low output of one hectare per 2-1/2 hours. Also, they tie relatively small bundles and cannot handle tall sesame. Because of the lack of an efficient binder, growing of shattering varieties has been possible only where a sufficiently large and low-cost labor force is available.

Semi-shattering Varieties -- Certain strains of sesame have been found which tend to hold the seed in the capsule, although the capsule is of the shattering type. Such varieties could be windrowed, left to dry for 2-3 weeks, and then threshed with a grain combine using a pick up attachment on the header. These varieties were found relatively recently, and not enough research has been done with them to establish that this practice is commercially profitable.

Non-shattering Varieties -- Non-shattering varieties are late-maturing, low-yielding, and difficult to thresh because of thick-walled capsules. All of these undesirable characteristics may be changed and improved with continued sesame breeding. Two or four rows of non-shattering sesame are windrowed together. For faster and better drying and threshing, windrows should be on the beds and not in the irrigation furrow. Grain combines with pick-up attachment can be used for threshing. To avoid excessive seed damage resulting in poor germination and increase of free fatty acids, combine cylinder speeds should be reduced. To compensate for reduced cylinder speed, it is necessary to increase the threshing surface by adding bars to the cylinders and concaves until the threshing surface is doubled. Optimum peripheral cylinder speeds are about 83,000 centimeters per minute (peripheral speed=cylinder diameter in centimeters x 3.1416 x cylinder speed in revolutions per minute). Cylinder - concave clearance should be adjusted to 6-7 millimeters. For best threshing, capsules not threshed the first time they pass between cylinder and concave should be returned by the tailings elevator to the cylinder for rethreshing.

Storage of sesame seed does not present major problems unless the percent of mechanically injured seed is high. In that case, free fatty acid content of the seed increases, resulting in inferior flavor and keeping quality of the seed and oil. Moisture content of sesame seed is a major factor in regard to storage. At 4 percent moisture, the reduction in viability of the seed stored

at room temperature was negligible after two years. At 7 percent moisture, the seed must be stored at temperatures lower than 10°C. at 10 percent moisture, viability of sesame declines very sharply.

Insects that damage sesame in storage, especially when seed moisture is high, are the following:

Tribolium castaneum Hb.

Tribolium confusum Jack. Duv.

Vryzaephilus surinamensis Lium.

Coreyra cephalonica St.

WEST PAKISTAN ENVIRONMENT AND CLIMATIC ANALOGS

SOIL

Most of the sesame in Pakistan is grown on alluvial soils and, to a lesser extent, on loess soils. Most of these areas have high clay fractions; nevertheless, all soil type gradations exist from sandy, to sandy loam, to heavy soils. Most of these soils could benefit from applications of commercial fertilizers. As mentioned earlier, sesame does not respond strongly to fertilization; therefore, the response of existing varieties should be studied in the corresponding areas where they are grown, using at first low or medium fertilization rates and a wide spectrum of elements.

WATER REGIME

In view of the sensitivity of sesame to water standing in the field, precautions should be taken never to leave irrigation water standing for more than a day in sesame fields. Some of the root rot diseases which plague sesame growers might be minimized if extensive flooding were avoided. A very efficient way of irrigating sesame would be to plant on raised beds 70 cm. apart and irrigate every other furrow. This practice has been found not only to reduce disease incidence, but also to reduce lodging to conserve water, and to move salts away from the planted row. Planting on raised beds would offer the added advantage of easier weed control by tractor cultivation. Finally, levelling of sesame fields and sub-soiling would reduce further the danger of over-irrigating sesame. A total of 500 mm. of water (including rainfall, if it occurs in the proper season) should be considered sufficient, on the average, for best sesame performance. This amount of water should be adjusted up or down depending on soil consistency.

WEATHER

Mean temperatures in Hyderabad are around 25-26°C. in March. Thus, there is a great deal of latitude in selecting the optimum planting date between March and late June so as to satisfy other requirements, i.e., labor, irrigation water availability, etc. In Lahore area, the planting dates could be varied in the April to late June interval. Judging from information from similar sesame growing areas, maximum yields should be expected from mid-May plantings, barring special problems particular to a given agricultural area.

DISEASES

There is very little that can be done on a field scale to reduce the incidence of phytopathological diseases except breeding for resistant varieties and using appropriate irrigation practices. In Hyderabad, especially, where rainfall is very limited, diseases should not be very serious if treated, disease-free seed is used and conservative irrigation practices are followed. In the case of phyllody disease, control of the jassid fly, which serves as a vector, could materially improve the situation. The jassid can be controlled fairly easily with one of several insecticides generally available. However, this control should be done simultaneously on neighboring cotton fields, which often are heavily infested with jassid. Treating sesame fields only would be ineffective.

Of the insects attacking sesame in Pakistan, aphids and the sesame leaf roller could present problems occasionally. Aphids can easily and efficiently be controlled with sprays of 1/2 lbs. active metasystrox per acre. Thiodon, at 1 lb./acre, will also control aphids, as well as some leaf and capsule miners and the lygus bug. Cool weather favors the build-up of aphids; therefore, in problem situations, delaying the date of planting might help. Finally, sesame varieties exhibit differential resistance to aphids and improvement through breeding is possible. The sesame leaf roller can be controlled with sprays of 0.2 DDT/WP or dusting with 5 percent BHC. However, when treatments are made late in the growing season, residues may be found in the seed. Chlorinated hydrocarbon residues would make the seed unexportable to the United States. Several other sesame importing countries do not have strict regulations in that respect.

AVAILABILITY OF ADAPTED GERM PLASM

Pakistan is in the same latitude zone as the sesame producing areas of southern Europe, U.S.A., Mexico, India, and China. Therefore, there are many varieties with the appropriate photoperiod response which should be tested in Pakistan. These varieties represent maturity groups ranging from 70-120 days, permitting a wide

choice of materials to fit the local rotation and work load needs. It is considered rather premature for Pakistan to direct a great deal of effort in testing non-shattering varieties which, at this point, are still plagued by a great number of problems.

IMPLICATIONS FOR YIELDS

Climatic conditions in Pakistan resemble those of the Imperial Valley in California. Sesame yields in the Imperial Valley, under irrigation and test plot conditions, have often reached 2500 kg. per hectare. These yields may be considered unrealistic since care is taken to collect the totality of the seed produced, which is not possible under actual field conditions. Nevertheless, the wide difference between these yields and those reported in Pakistan suggest that considerable improvement should be possible in the latter, provided the factors limiting sesame yields could be identified.

IMPLICATION FOR MULTIPLE CROPPING SYSTEMS

The versatility of sesame in terms of maturing groups and planting dates makes it a rather easy crop to fit into a cropping system so as to avoid excessive work load peaks and competition for labor and equipment used for other summer crops. Furthermore, sesame can be accommodated in a variety of rotations with winter crops such as early cereals, horsebeans, berseem clover, vetch, vetch-oats mixtures, and possibly winter vegetable crops.

STATUS OF RESEARCH

Sesame research is currently carried out in two centers:

- University of California, Plant Sciences Department, Riverside, California 92502:

  Researcher is Professor D. M. Yermanos.

- Centro de Investigaciones Agronomicas, Ministerio de Agricultura, Maracay, Venezuela:

  Researcher is Professor Bruno Maggani P.

Two major research efforts in the above centers are the development of non-shattering varieties of sesame and the development of hybrid varieties.

Non-shattering varieties have been available for over 15 years. In spite of that, they are not grown commercially because of their low yields and difficulty of threshing. Breeding work has succeeded in developing strains which produce a little more than half of the yield that shattering varieties can produce in a given location. These yields must be improved considerably, however, before farmers will accept the non-shattering varieties for commercial production.

Sesame has been found to exhibit considerable hybrid vigor. Research is underway to find chemical sprays which will cause male sterility in varieties of sesame which could be used as female parents for the production of hybrid seed. Encouraging results have been obtained with Dalapon, but additional work is required before it will be possible to use this technique for seed production.

Other problems investigated are chemical weed control, mechanical harvesting, fertilization, oil and protein production, optimum plant populations, and decortication. One significant discovery was to find three herbicides which apparently can be used on sesame with encouraging results. These chemicals are not registered for sesame and no information is yet available on residues in the oil or meal after their use. These chemicals are: Lasso (by Monsanto), Diphenamid (by Eli Lilly), and Prefar (by Stauffer) at rates of 2-4 lbs./A.

PEANUTS

PEANUTS [32]

WORLDWIDE PRODUCTION OF PEANUTS

INHERENT PRODUCTION POTENTIAL PER HECTARE

The average yield of peanuts in the United States in 1970 was about 2300 kg. per hectare. Yields of about 5600 kg. per hectare have been obtained by individual growers. Inherent production potential may be as much as 8400 kg. per hectare.

QUALITY CHARACTERISTICS RELATED TO POTENTIAL USES

Peanut seed contains about 50 percent oil, 20 to 35 percent of which is the polyunsaturated fatty acid, linoleic acid. Peanuts are an excellent source of certain B vitamins, with a high level of niacin and appreciable quantities of thiamine and riboflavin. They contain some vitamin E and vitamin K, and moderate levels of minerals. Peanut oil is widely used as a liquid cooking oil, is excellent for pan or deep-fat frying because of its high smoke point, and is used in pastries, salad dressings, mayonnaise, and margarine or margarine-like products. Peanut oil is suitable for human consumption without special processing. The oil consists of 20-35 percent linoleic acid, 40-60 percent oleic acid, and 15-20 percent saturated fatty acids. It is almost entirely free of linolenic acid and its attendant flavor and stability problems.

In many parts of the world, refined peanut oil is a preferred oil for human consumption and commands a higher price than oil of cottonseed, soybeans, or palm kernels. To a limited extent, peanut oil is used as a base in certain cosmetics, and is used in some pharmaceutical preparations. Crude peanut oil is used to a limited extent in manufacture of soaps and detergents.

Peanut cake or meal, a byproduct of oil extraction with a protein content of about 55 percent, is widely used as a nutritious high-protein component in feed for livestock and poultry. Peanut meal from high-quality peanuts and processed under sanitary conditions is suitable for human consumption. Meal or cake made in

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32/ W. K. Bailey, Leader, Peanut Investigations, Agriculture Research Service, U.S. Department of Agriculture, prepared this section.

crude small presses, such as the Indian ghani, and containing high residual oil is consumed as food in China, India, Indonesia, Nigeria, and elsewhere in Africa. In Indonesia, for example, much of it is converted to "ontjom," nutritious white, orange, or red products made by treatment of the cake with fungi. In West Africa, the cake is fried in groundnut oil.

High quality peanut cake can be ground finely to produce peanut flour that is easily digested and reasonably well assimilated. For adults, peanut flour protein has a digestion coefficient of 99 percent and a biological value of 56 to 87 percent. Peanut flour can be used in a wide variety of ways to supplement human diets; for example, it can be used in local gruels and porridges, soups, sauces, puddings, confections, and bakery products. At levels under 100 g./day, peanut flour comprises a useful supplement which increases the growth rate and general health of undernourished children. Therapeutic uses include the treatment of advanced pellagra, glossitis, and kwashiorkor. In some countries, a "milk" has been made from peanut flour and fed to children.

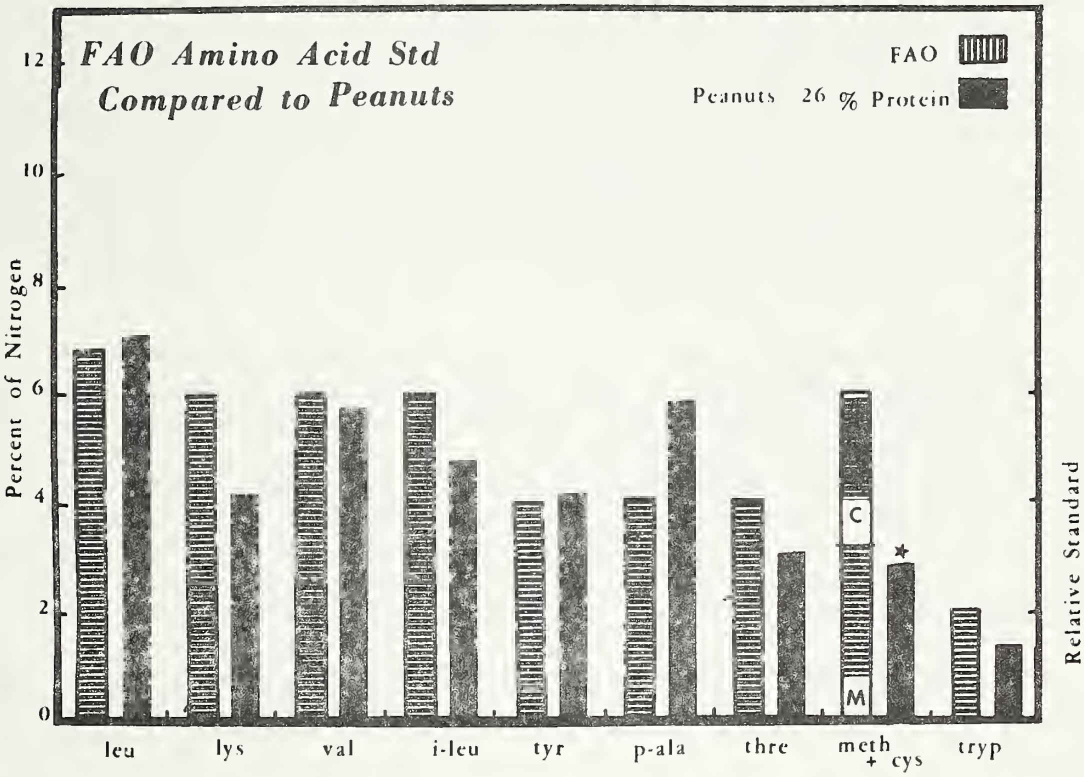
Peanut cake can serve as an excellent source of protein isolates. About 90 percent of the total nitrogen in oil-free peanut cake is water soluble, so extraction of the protein is comparatively simple.

Peanuts require no processing at all to make them suitable for human consumption. The highly nutritious seed may be eaten raw as they come from the shell. For processing into other desirable forms, only heat is required. Peanuts have an advantage over other oilseed crops such as soybeans and cottonseed in that no special processing is required to make the oil, cake, or extracted protein suitable for consumption by humans or other animals.

In the United States and Israel, peanuts are grown solely for human consumption in more or less their natural form, rather than for oil and meal. They are used principally as peanut butter, as salted peanuts, or in candy and other confections; or they are roasted in the shell. Peanuts are among the most nutritious of our natural foods. Among crop plants, they are unsurpassed in total food energy, with more than 5,500 calories per kg. of shelled seed. Peanut seed contains 25 to 30 percent easily digested protein of high biological value. In dietary essential amino acids, peanut protein is low in methionine and, to a lesser extent, in lysine. Peanut protein approaches, but does not equal, the protein of soybeans in amino acid balance and biological efficiency.

Amino acids in peanut protein and in FAO standard are shown below.

Fig. 2.--FAO amino acid standard compared to peanuts.



GROWTH CHARACTERISTICS AND TOLERANCE OF VARIOUS CONDITIONS

Peanuts usually are grown on sandy, sandy loam, or friable sandy clay loam soils. Peanut plants have a capacity to grow luxuriantly and produce bountifully when grown on heavier soils. The choice of the light and friable soils for producing the crop is largely because of the critical importance of timeliness in many cultural operations and the need for a soil which will not adhere tightly or in volume to the peanut pods at digging time. The need for comparatively clean pods at digging is probably the major consideration.

Excellent surface and subsurface drainage is a must for successful peanut production. The crop will not tolerate poor drainage. Peanuts are grown successfully on soils with a fairly wide range of pH, from 5.0 to about 8.0. In the U.S. a soil pH of about 6.3 to 6.6 is considered near the optimum. Most of the peanuts in this country are grown on soil with a pH between 5.0 and 7.0. In New Mexico, where soil pH usually exceeds 7.0, difficulty is encountered with mineral nutrition of peanut plants, with increasing frequency as the pH approaches 8.0.

Peanuts appear relatively sensitive to soil salinity. In research in Israel with artificially salinized plots, maximum yields were obtained at a salinity level of 3,200 micromhos/centimeter or less. A level of 4,700 micromhos/centimeter reduced yield by 50 percent and about 6,500 micromhos/centimeter resulted in no yield. Results of this study also indicate that, for leaching to be effective in correcting salinity for peanuts, salts must be removed beyond the full rooting depth in the soil profile and not just from the main root zone.

Usually, when peanuts are grown on medium to highly fertile soils which are moderately well supplied with calcium, their response to direct applications of fertilizer has been meager. Only under conditions where soil tests show certain element(s) to be deficient have moderate to appreciable increases in yield been obtained by the addition of commercial fertilizer containing these elements. At times, applied nitrogen has resulted in substantial increases in yield of Spanish peanuts, but Virginia type peanuts have rarely responded to applied nitrogen in this country. On most soils where peanuts are grown in the United States, additional phosphorus or potassium is rarely beneficial. Peanuts have failed to respond to phosphorus and potassium applications even when phosphorus and potassium deficiency symptoms show up on other crops. However, the more fertile the soil, the higher the yield of peanuts. As a consequence, a practical approach to improving the yield of peanuts by fertilization is to apply additional fertilizer to the crop that precedes peanuts in the rotation, thereby building up the general fertility level of the soil.

The peanut is a unique crop plant in that certain nutrient elements can be and are absorbed from the soil by the pegs and developing pods as well as by the roots. The most consistent and predictable response of peanuts to applied nutrients in the United States has been the response to calcium. A source of calcium must be available to the developing pegs and pods in the fruiting zone of the soil. In general, the larger the genetic seed size of a variety, the more essential is a liberal supply of calcium in the fruiting medium to insure acceptable pod and seed development. Conversely, the smaller the genetic seed size, the less exacting is the requirement for a liberal supply of available calcium in the fruiting zone. The adequacy of calcium in the fruiting zone of the soil can have a striking influence on both the yield and market grade of the crop.

If soil tests indicate a low level of calcium, application of some form of ground limestone to the soil several months prior to planting will usually provide adequate calcium in the fruiting zone for excellent pod fill and yield of Spanish peanuts. For larger seeded varieties, we recommend applying agricultural gypsum or landplaster directly onto the plants about the time of full bloom.

Another mineral that is deficient for peanuts in some fields in this country is boron. When soil tests or peanut seed characteristics indicate that boron is deficient, this can be corrected by adding boron to the soil at the rate of one pound per acre.

The peanut is a legume and, as such, obtains atmospheric nitrogen through symbiosis with nitrogen-fixing bacteria. <u>Rhizobium</u> sps. of the cowpea or tropical legume type are symbiotic with peanuts. Nitrogen-fixing bacteria are well distributed in soils in areas where peanuts or one of the other hosts of the <u>Rhizobium</u> sps. have been grown, so seed inoculation is not required. Seed inoculation might be beneficial when peanuts are planted on recently cleared land or in fields or areas where the crop has never been grown before. Strains of <u>Rhizobium</u> sps. have been identified which are much more effective in inducing vigorous growth and development of peanut plants under conditions where the plants have access to no nitrogen from other sources than are strains obtained from nodules of peanuts growing in commercial fields. However, attempts to establish these highly effective strains in peanut fields have failed.

In the peanut producing soils of Israel where symbiotic nitrogen-fixing <u>Rhizobium</u> sps. have not been established successfully, peanuts respond to applications of nitrogen fertilizer in much the same way as cotton and corn respond in this country.

Peanuts have a reputation as a soil-depleting crop when the entire plant, except for some of the smaller roots, is removed

from the land at harvest. However, when all of the plant residue except the pods is returned to the land at harvest, the peanut is probably no more soil-depleting than any other highly productive crop.

The peanut has a reputation of being a drought resistant crop, perhaps because of its deep extensive root system which enables the plant to seem to thrive under conditions of soil moisture where other crop plants are adversely affected. However, a shortage of soil moisture during the period of pod and seed development can seriously impair the productiveness of the crop, even though the vegetative portion of the plants may show little adverse effect other than somewhat reduced growth.

Excellent crops of peanuts are often produced in the United States when rainfall amounts to 50 to 55 cm. during the 4 to 5 months the crop is growing. An advantageous distribution of rainfall for peanuts in the United States would be an average of about 2 cm. per week during first 6 or 8 weeks of the growing season, increasing to an average of 2.5 to 3 cm. during the 8 or 10 weeks of rapid pod and seed development, tapering off during the final 2 or 3 weeks to an average of about 1.5 cm. a week, with little or no rain during the last week or 10 days prior to digging and, subsequently, during harvesting and curing.

Lack of adequate soil moisture during the critical period of pod and seed development is probably the greatest single limiting factor in yield of peanuts in the United States. The average yield of pods in 1970 was about 2,300 kg./ha. When the crop is grown under irrigation, yields rarely are below 3,300 kg. and yields of 4,500 to 5,600 are not unusual.

Peanuts are not sensitive to day length insofar as triggering reproduction is concerned.

Like cotton, the peanut is a warm season crop, and is sensitive to frost. Studies at constant temperatures under controlled conditions indicate that the optimum for germination, growth, and fruiting of the peanut is about 25 to 30°C. For successful production, peanuts require a growing season of 4 to 6 months, during which temperature during the day reaches 26-32°C and is usually no lower than 16-21° at night. Higher day and night temperatures (36-38° maximum and 21-24° minimum) will usually hasten maturity. Maximum temperature as low as 24° during the day, together with a minimum temperature as low as 10° at night, bring peanut pod and seed development to a virtual standstill if this pattern persists for longer than a few days. In the United States, peanuts can be grown successfully on a commercial basis about as far north as cotton, which requires a growing season with about 200 frost-free days for successful production.

When grown in southern Georgia, early maturing commercial varieties mature in 120 days and the latest varieties mature in 150 days. Genotypes are available which mature in 90 to 160 days in Georgia, giving a range of 70 days in earliness which is associated with genetic make-up of the crop. Temperature has a striking influence on duration from planting to maturity. Varieties which mature in 120 days in Georgia may require 150 to 160 days to reach full maturity when grown in Oklahoma, and 180 days when grown at an elevation of 1,200 m. in Rhodesia. In certain places in the tropics, where temperatures are high both day and night, these same varieties mature in 90 to 100 days. Thus, range in maturity of a given variety associated with temperature under which the crop is grown can be as much as 90 days.

Peanuts are subject to many diseases and insects which, unchecked, can sharply curtail production. Estimated average annual losses in production caused by various peanut diseases, nematodes, and insects in the United States during the period 1951-60 are as follows:

Leafspot	10.0	percent
Stem rot, or southern blight	7.5	"
Pod rots	2.5	"
Root rots	2.5	"
Seedling death or stunting	2.5	"
Seed decay after planting	2.0	"
Collar and crown rot	1.0	"
Nematodes	3.0	"
Insects	3.0	"

Production losses where efforts to control pests are minimal would likely greatly exceed those reported here. Some peanut pests, such as cercospora leafspots, are worldwide in distribution and severity, but others vary from country to country, both in prevalence and severity. Peanut rust is found only in the Americas and islands of the West Indies; peanut rosette, a highly destructive virus disease, is found only in parts of Africa and Asia. Major insect pests tend to differ from country to country.

Practical procedures for suppressing diseases include chemicals, cultural practices, and crop rotation for certain of the diseases; for others, no effective control is known. A similar situation exists for insect pests.

Contrary to experience with other crops, little useful genetic resistance to disease and insect pests has been found in cultivated peanuts. Varying degrees of field tolerance to certain pests have been reported, but, frequently, such apparent reactions are associated with differences in physiological maturity of the plant, fruit load, or both. However, the entire world collection of peanut germplasm has not yet been systematically screened for resistance to major diseases and insect pests.

Certain wild *Arachis* species show a high level of resistance or immunity to such pests as cercospora leafspots, peanut rosette, peanut stunt virus, peanut rust, northern rootknot nematode, and one species of mite. Unfortunately, most of the wild *Arachis* species which show such resistance or immunity cannot be crossed successfully with cultivated peanuts, although efforts to achieve such crosses are continuing in the United States and elsewhere.

SPECIAL HARVESTING AND STORAGE PROBLEM FOR PEANUTS

Peanuts present a special harvesting and storage problem. The plant has an indeterminate fruiting habit and, at harvest, moisture content of individual seed on the same plant may range from 60 to 70 percent down to about 30 percent. The moisture content of all of these seeds must be reduced to 7 or 8 percent for safe bulk storage. If no rain falls and drying conditions are favorable following digging, drying poses no problem. Pods may be permitted to dry in the field while attached to the plants in windrows, or they may be picked at digging, or any time thereafter, and dried under controlled conditions with ambient or slightly heated air. If drying proceeds steadily, high quality cured peanuts that are free of objectionable molds usually can be anticipated. However, if the period of drying is prolonged (2 or 3 weeks), if a major interruption occurs once drying is well under way, or if seed moisture is increased to 20-25 percent by rain after having reached 15 percent or lower, seed so exposed may become contaminated by aflatoxins if temperature and relative humidity are high.

Aflatoxins are metabolites of the ubiquitous fungus *Aspergillus flavus*, or *A. parasiticus*. They are highly toxic to certain species of warm blooded animals. Direct evidence implicating or exonerating aflatoxins as harmful to man is lacking. Special efforts are made by all segments of the peanut industry and the U. S. Government to insure that no peanut seed, peanut products, or meal with aflatoxin content above 20 p.p.b. enter the food or feed trade. This 20 p.p.b. "working level" will likely be lowered as more sensitive bioassay procedures are developed to supplement the highly precise chemical detection procedures already in use.

Most peanut seed which contains aflatoxins becomes contaminated as a result of adverse conditions during drying or subsequent storage. However, if drying proceeds at a steady pace and is not too prolonged, the fungus remains quiescent. Under adverse conditions for drying, the fungus grows vigorously and produces the toxins. Some peanut seed may be infected by *A. flavus* prior to digging and, under some circumstances, become heavily invaded by the fungus during drying. Aflatoxins in seed

at the time of digging appear to be associated sometimes with moisture stress during the latter part of the growing season.

If rain or high humidity are likely during field drying, the aflatoxin hazard can be reduced by inverting the plants in the windrow in such a way that no pods are in contact with the soil; drying can be completed successfully within a few days. If rain during harvest is unavoidable, prompt steady drying of the pods under controlled conditions with ambient or slightly heated air to a seed moisture level of 7 or 8 percent might be necessary to avoid contamination of cured seed with aflatoxins.

When peanut seeds which are contaminated with aflatoxins are crushed for oil, most of the toxins remain in the meal and the small portion present in the crude oil is eliminated when the oil is refined. Peanut meal which contains an appreciable level of aflatoxins is not suitable as food for man or animals.

If peanut seed or the cake or meal therefrom are to be used as food for humans, precautions should be taken to ensure that the seeds are not exposed to too high temperature during drying, and that drying does not proceed too rapidly. Research has shown that peanut seed dried at a temperature of 50°C. or higher develop an obvious off-flavor on roasting. Seed dried too rapidly (in less than 3 days) tend to split badly, lose their seedcoats on shelling, and have a bland flavor on roasting. Temperature of peanut seed inside pods exposed to sunlight and in direct contact with the soil may be 16° higher than ambient shade air temperature. Seed inside pods in direct sunlight well above the soil attain temperatures that usually are 5° lower than seed in pods so exposed in contact with the soil. Thus shelling and processing impairment is less likely to occur in peanuts that are inverted for drying in the windrow than in those drying in a random windrow where many pods will be in direct contact with the soil. Under all but most extreme temperature conditions, the effectiveness of inverting plants at digging in helping to insure prompt uniform drying of pods probably more than offsets possible danger of impairment of shelling and processing quality of the cured seed.

WEST PAKISTAN ENVIRONMENT AND CLIMATIC ANALOGS

SOIL, WATER, WEATHER, AND DISEASES

More than 60 percent of the 35,000 ha. of peanuts in West Pakistan in 1968-69 were grown in the contiguous provinces of Jhelum, Rawalpindi, and Campbellpore. These are located in the subhumid area of the subtropical continental lowlands in the northern part of the Indus Plains between the 32.5° and 34.0° N

parallels, adjacent to India's Punjab State. Production in neighboring provinces of Mardan, Peshawar, Gujarat, Shahpur (Sargodha), Jhang, Hazara, and Mianwali brings the area in peanuts in the northern part of the country up to more than 70 percent of the total. Remaining production area is distributed among most provinces in the eastern part of West Pakistan. (See map on next page.)

Average annual rainfall in most of these provinces ranges from about 50 to 85 cm. The bulk of the year's rainfall usually occurs during the summer monsoon, with precipitation during June, July, August, and September accounting for 70 to 85 percent of the annual total. At times, rainfall is torrential. Rainfall is so unpredictable in most of this area and other parts of West Pakistan that rarely is successful crop production possible without supplemental irrigation. The spring and autumn months are practically rainless throughout the Indus Plains.

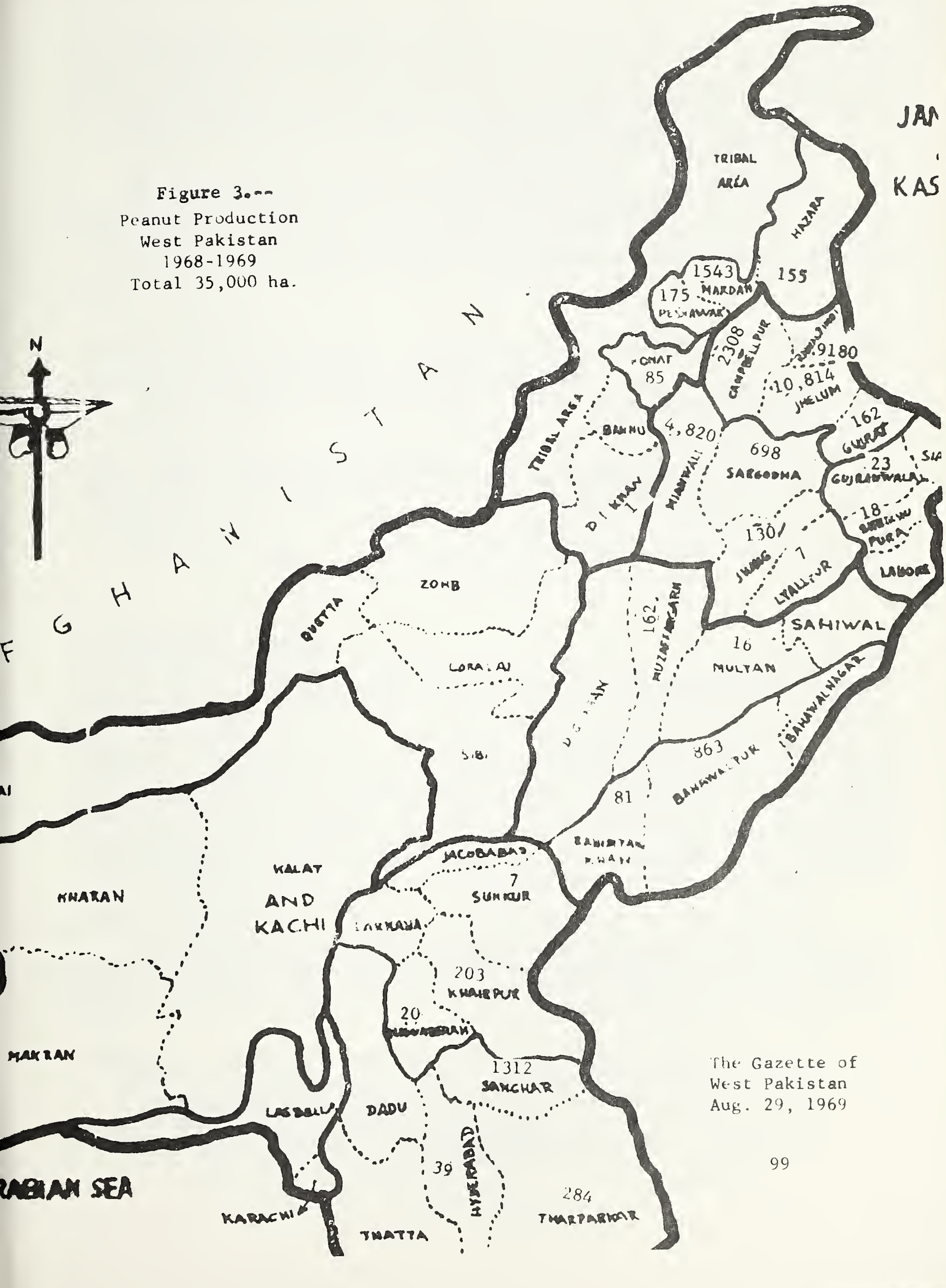
It seems unlikely that shortage of calcium in the fruiting zone of peanuts would be a problem in West Pakistan, because the calcium content of soils is generally high. There are indications that peanuts might respond favorably to application of phosphorus in some areas. A possible response to nitrogen, suggested in one area, might be associated with poor or ineffective nodulation.

Most of West Pakistan's agricultural wealth comes from the Indus Plains, a huge alluvial plain drained and watered by the Indus River and its seven large tributaries, all of which join the Indus at least 400 miles before it reaches the sea at the southern tip of the country. Soils of West Pakistan which are suitable for agricultural purposes are mostly of alluvial origin, generally have an alkaline reaction, and many are calcareous. Salinity and waterlogging are serious problems. Low rainfall, high temperatures, high salt content of river water that is used for irrigation, and, at times, floods many low-lying areas all tend to accentuate the soil salinity problem.

The high pH, saline nature and tendency for waterlogging of the soils; the generally high salt content of the river water available for irrigation; and the unusually high temperatures which prevail for several months during the summer in West Pakistan are situations that are without parallel in the peanut producing areas of the United States. Such ecological conditions are doubtless critical factors in determining where peanuts are grown in West Pakistan and in determining into what additional areas, if any, expansion of production could be undertaken advantageously insofar as capability of the crop to produce is concerned.

The unusually high temperatures which prevail during the summer months might tend to delay peg elongation and pod and seed development, thereby lengthening the period from planting to

Figure 3.--
Peanut Production
West Pakistan
1968-1969
Total 35,000 ha.



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maturity. Most peanuts in West Pakistan are planted between February 15 and June 1, and are dug from September 1 through December. The same genotypes grown in the United States under milder summer temperatures (average rarely above 27°C., and usually well below 27°C.) mature in about 140 days in south Georgia, in contrast to about 200 days in West Pakistan.

Information on the identity and severity of disease and insect pests of peanuts in West Pakistan is inadequate to warrant suggestions as to the extent to which experience with such pests in this country and elsewhere might have implications for West Pakistan.

AVAILABILITY OF ADAPTED GERM PLASM AND IMPLICATIONS FOR YIELDS

At least two improved, productive, locally-adapted varieties of peanuts, No. 334 and No. 45, are available and are now in production in West Pakistan.

According to Yearbook of Agricultural Statistics 1968, Fact Series No. VII, issued in 1969 by the Ministry of Agriculture and Works, Government of Pakistan, the average yield of peanuts in West Pakistan from 1960-64 was 1,257 kg./ha. The average yield in the United States during this same 5-year period was 1,465 kg./ha.

In the Lahore region, where most of West Pakistan's peanuts are grown, yields of 550 to 5,500 kg./ha. have been reported. Yields of 1,653 to 3,674 kg./ha. in Peshawar and 2,057 to 3,490 kg./ha. in the Hyderabad region have been reported. Such yields compare favorably with representative yields in the United States.

Considering the apparent lack of extensive research on peanuts in West Pakistan, the favorable yields suggest that peanuts might be as well adapted, and perhaps even better adapted, to production in West Pakistan than in the United States. The favorable representative yields in the Hyderabad area indicate that peanuts can be grown successfully in parts of the country other than the north, where most of the crop is grown at present.

In a report on "A Study of the Potential for Increased Oilseed Production in West Pakistan," issued in August 1967 under the auspices of the United States Agency for International Development/Pakistan, Ralph S. Matlock recommended a 5-fold increase in acreage for peanuts. Matlock stated:

> "The groundnut (peanut) is the oilseed and pulse crop most ready for expanded acreage. This is evidenced by good runner varieties already in production, so grower experience (70,000 acres reported in 1967) and some marketing and processor experience have been gained. Yields and returns have been

encouraging, and some research has been conducted. It is recommended that West Pakistan plant 350,000 acres of No. 334 and No. 45 groundnuts on the irrigated sandy soils in areas around Campbellpur, along the east bank of the Indus south of Derma Ismail Khan, and perhaps on irrigated sandy land from Kohat to Bannu."

In addition, Matlock suggested production procedures which should insure favorable yields, and types of research which should help insure higher yields in the future.

IMPLICATION FOR MULTIPLE CROPPING SYSTEMS

On the basis of information available, peanuts might fit advantageously into a multiple cropping system with wheat, which is widely grown in northern areas where peanuts are now grown and in areas which Matlock has suggested for expanded production of peanuts.

STATUS OF PEANUT PRODUCTION RESEARCH

IN THE UNITED STATES

About 46 scientist man years/year are now devoted to peanut production and related mycotoxin research in the United States. However, this level of research is of comparatively recent origin. It was not until 1940 that Congress appropriated funds for peanut production research by the U. S. Department of Agriculture. Much of the increase in peanut research has occurred since recognition of the aflatoxin problem in 1964. Many scientists engaged in peanut research have other research interests and responsibilities. Consequently, much of the current research on problems of peanut production may be described, appropriately, as fragmentary. This appears to be the situation in other parts of the world also.

Here is a list of principal centers of peanut production research in the United States, together with names of many of the scientists involved and the general nature of the research underway:

ALABAMA

- Auburn University, Auburn:

  A. C. Mixon, Agronomist (USDA).
  G. A. Buchanan, Agronomist.
  N. D. Davis, Pathologist. (continued)

U. L. Diener, Pathologist.
N. H. Bass, Entomologist.
A. J. Lyle, Pathologist.
F. Adams, Soil scientist.
M. D. Bond, Extension agronomist.

Cultural practices; variety evaluation; breeding for resistance to toxin producing molds; nature and control of diseases and insects; herbicides; soil fertility; root development; mycotoxins; and extension education.

FLORIDA

- University of Florida Agricultural Experiment Station, Gainesville:

A. J. Norden, Agronomist.
C. R. Miller, Plant pathologist.

Genetics, breeding, variety evaluation, diseases, breeding for resistance to toxin-producing molds. The most successful variety improvement program for Virginia type peanuts in United States.

GEORGIA

- University of Georgia Agricultural Experiment Station, Experiment:

C. R. Jackson, Pathologist.
H. W. Boyd, Pathologist.
D. H. Smith, Pathologist.
G. Sowell, Pathologist (USDA).

Nature and control of foliage and soil-borne diseases; screening genotypes for resistance to diseases; mycotoxins.

- University of Georgia Coastal Plain Experiment Station, Tifton, Georgia:

M. E. Walker, Agronomist.
S. A. Parham, Agronomist.
D. K. Bell, Pathologist.
B. Doupnik, Pathologist.
L. W. Morgan, Entomologist.
J. R. Stansell, Agricultural Engineer.
J. L. Shepherd, Agricultural Engineer.
J. L. Butler, Agricultural Engineer (USDA).
J. M. Troeger, Agricultural Engineer (USDA). (continued)

R. O. Hammons, Geneticist (USDA).
E. W. Hauser, Agronomist (USDA).
N. A. Minton, Nematologist (USDA).
D. B. Leuck, Entomologist (USDA).
J. F. McGill, Extension Agronomist.
L. E. Samples, Extension Agricultural Engineer.

Genetic; breeding; variety evaluation including screening for resistance to insects; cultural practices; fertilizer requirements; herbicides; irrigation; nature and control of diseases, nematodes, and insect pests; mycotoxins; mechanization of production, harvesting, and curing; extension education.

MARYLAND

- Plant Science Division, ARS, USDA, Plant Industry Station, Beltsville, Maryland:

W. K. Bailey, Horticulturist, Leader of peanut production research, Oilseed and Industrial Crops Research Branch.
J. M. Good, Nematologist, Leader of nematode investigations, Crops Protection Research Branch.

NEW MEXICO

- New Mexico Agricultural Experiment Station Plains Branch Station, Clovis, New Mexico:

D. C. H. Hsi, Pathologist, Diseases and variety evaluation of Valencia type peanuts.

NORTH CAROLINA

- North Carolina State University Agricultural Experiment Station, Raleigh, N. C.:

W. C. Gregory, Geneticist.
M. P. Gregory (Mrs.), Geneticist.
D. A. Emery, Geneticist.
J. C. Wynne, Agronomist.
W. V. Campbell, Entomologist.
T. T. Hebert, Pathologist.
F. R. Cox, Soil Scientist.
R. P. Moore, Seed Physiologist.
J. N. Sasser, Nematologist.
J. W. Dickens, Agricultural Engineer (USDA).
E. O. Beasley, Extension Agricultural Engineer.
J. W. Glover, Extension Agricultural Engineer.
J. C. Wells, Extension Pathologist.
A. Perry, Extension Agronomist.

Basic genetics, cytogenetics and cytotaxonomy of genus *Arachis*; mutation breeding; interspecific hybridization between cultivated and wild *Arachis* species; breeding improved varieties of large-seed Virginia type peanuts; variety evaluation; nature and control of virus and other diseases; nematodes and their control; insects and their control including genotypic resistance; soil fertility; seed physiology; herbicides; harvesting and curing; mycotoxins; extension education.

OKLAHOMA

- Oklahoma State University Agricultural Experiment Station, Stillwater, Oklahoma:

  R. S. Matlock, Agronomist.
  P. W. Santleman, Agronomist.
  C. C. Russell, Nematologist.
  D. F. Wadsworth, Pathologist.
  G. L. Barnes, Pathologist.
  L. D. Tripp, Extension Agronomist.
  J. S. Kirby, Agronomist.
  D. J. Banks, Geneticist (USDA).
  J. Q. Lynd, Soil Microbiologist.
  J. F. Stone, Soil Physicist.
  J. G. Porterfield, Agricultural Engineer.

  Genetics; cytogenetics; development of procedures for transfer of desirable genes from wild *Arachis* species to cultivated peanuts; breeding of Spanish type varieties; variety evaluation; cultural practices; herbicides; fertilizer and irrigation requirements; disease, insect and nematode control; mycotoxins; harvesting and curing; extension education.

TEXAS

- Texas A & M University Agricultural Experiment Station, College Station, Texas:

  W. H. Thames, Nematologist.
  R. E. Pettit, Pathologist.
  J. W. Sorenson, Agricultural Engineer.
  N. K. Person, Agricultural Engineer.
  Olin Smith, Agronomist.
  B. R. Spears, Extension Agronomist.
  D. L. Ketring, Physiologist (USDA).
  J. W. Smith, Jr., Entomologist.

Nature and control of diseases, nematodes, and insects; mycotoxins; genetics and breeding of Spanish type varieties; variety evaluation; mechanization of harvesting and curing; studies of factors involved in growth, flowering and fruiting, seed dormancy and viability; extension education.

- Texas A & M Plant Disease Laboratory, Yoakum:

  A. L. Harrison, Pathologist.
  T. E. Boswell, Pathologist.

  Nature and control of diseases and nematodes; cultural practices including herbicides; variety evaluation including resistance to disease.

- Texas A & M Tarleton Experiment Station, Stephenville, Texas:

  C. E. Simpson, Geneticist.
  S. Newman, Agronomist.

  Genetics; cytogenetics; breeding and variety evaluation; cultural practices, irrigation and fertilization.

VIRGINIA

- Virginia Agricultural Experiment Station, Blacksburg, Va.:

  M. G. Hale, Physiologist.
  A. J. Lambert, Extension Agricultural Engineer.
  L. I. Miller, Pathologist.
  S. A. Tolin, Pathologist (virology).
  G. J. Griffin, Pathologist.

  Harvesting and curing equipment and procedures; nature and control of virus and soil-borne diseases and nematodes; extension education.

- Tidewater Research Station, Holland, Virginia:

  R. W. Mozingo, Agronomist.
  D. L. Hallock, Soil Scientist.
  J. C. Smith, Entomologist.
  O. E. Rudd, Physiologist (weed control).
  A. H. Allison, Extension Agronomist.
  K. H. Garren, Pathologist (USDA).
  D. M. Porter, Pathologist (USDA).
  P. H. van Schaik, Agronomist (USDA).
  G. B. Duke, Agricultural Engineer (USDA).
  F. S. Wright, Agricultural Engineer (USDA).
  J. L. Steele, Agricultural Engineer (USDA).

Genetics; breeding and evaluation of Virginia type varieties; soil fertility studies; nature and control of diseases and insects; screening for genetic resistance to diseases and insects; pod and seed mycoflora; mycotoxins; weed control; mechanization of peanut growing, harvesting, and curing; extension education.

IN WEST PAKISTAN

The present status of peanut production research in West Pakistan is difficult to assess because of a paucity of published information that could be found on the subject. Some work on variety improvement, fertilization, cultural practices, and control of pests is evident, but extent and effectiveness of this research effort cannot be evaluated with the information available. The availability of two improved, productive, locally-adapted varieties of runner peanuts for production indicates measurable progress in variety evaluation.

Two countries that might be sources of research information about peanut production which could have important implication for peanut production in West Pakistan are Israel and India. Israel might be a source of useful information about soil moisture and irrigation requirements for efficient production, soil salinity, and seed inoculation.

India could be a source of high-yielding varieties that might be well-adapted for production in West Pakistan. Improved cultural practices and varieties developed for effectively controlling diseases and insects in India's Punjab State, adjacent to the area where most peanuts are grown in West Pakistan, might be directly applicable to peanut production in West Pakistan with only minimum, if any, modification.

An appreciable amount of research has been conducted on peanuts in India's Punjab State since partition. Several improved high-yielding varieties have been developed and are now in production. Also considerable information has been developed on control of diseases and insects and on cultural practices and irrigation in an environment similar to that under which most peanuts are grown in West Pakistan.

Two men who are engaged in peanut production research at Punjab Agricultural University, Ludhiana, India, are listed in the next section, "Other Research." A highly knowledgeable man about peanut production in India's Punjab is J. L. Dalal. Mr. Dalal had some 15 years experience as a breeder and agronomist in peanut research in the Punjab before he transferred in 1964 to the Punjab State Department of Agriculture, with responsibility for that Department's program for peanuts and other oilseeds.

The extent to which the results of peanut production research in India are being applied already in West Pakistan cannot be determined from the information available.

OTHER RESEARCH

Here is an incomplete list of centers of peanut production research in other parts of the world, together with names of certain of the scientists involved and a general indication of the nature of the research:

Latin America

ARGENTINA

. Agricultural Experiment Station, Manfredi, Cordoba:

J. R. Pietrarelli, Agronomist.
M. J. Frezzi, Pathologist.

Genetics; variety improvement and evaluation; cultural practices; nature and control of diseases; mechanization of production harvesting and curing.

BRAZIL

. Institute of Agronomy, Campinas, Sao Paulo:

Variety testing in States of Sao Paulo, Bahia, Minas Gerais, and Pernambuco; genetics; breeding; cultural practices; nature and control of diseases and insects.

VENEZUELA

. Center of Agronomic Investigations, Maracay, Arugua:

B. Mazzani, Agronomist.
G. Malaguti, Pathologist.

Variety improvement; cultural practices; nature and control of diseases.

Europe

THE NETHERLANDS

. Laboratory of Tropical Agriculture, Wageningen:

G. G. Bolhuis, Agronomist, Physiology and production research.

FRANCE

- Institut de Recherches pour les Huiles et Oleagineaux, Paris:

  P. Giller, Variety development and testing, particularly for West African countries.

ENGLAND

- Tropical Products Institute, London:

  Research on mycotoxins.

- Commonwealth Mycological Institute, Perry Lane, Kew, Surrey:

  G. A. Gilman, Pathologist, Studies on pod, seed, and soil mycoflora in relation to aflatoxins.

<u>AFRICA</u>

SOUTH AFRICA

- College of Agriculture and Research Institute, Potchefstroom:

  J. P. E. Sellschop, Agronomist, Variety improvement and evaluation; cultural practices.

- Plant Protection Institute, Department of Agricultural and Technical Services, Pretoria:

  P. J. Klesser, Pathologist, Nature and control of virus and other diseases; mycotoxins.

NIGERIA

- Institute for Agricultural Research, Ahmadu Bello University, Samaru, Zaria:

  Colin Harkness, Breeder.
  D. McDonald, Pathologist.
  A. M. Fowler, Pathologist.
  H. Caswell, Entomologist.

  Variety improvement and evaluation; cultural practices; agronomic aspects of mycotoxins; breeding for high oil content; breeding for cercospora leafspot and rosette virus resistance; nature and control of diseases and insects.

SENEGAL

- Centre de Recherches Agronomiques, IRAT, Bambey:

  P. Silverstre, Agronomist.
  J. C. Mauboussin, Breeder.
  J. F. Poulain, Soils Agronomist.
  M. Delassus, Pathologist.

  Variety improvement; cultural practices; fertilization; diseases and other pests; aflatoxin studies.

GAMBIA

- Department of Agriculture, Cape St. Mary:

  L. J. Marenah, Variety improvement and evaluation; agronomic trials.

MALAWI

- Agricultural Research Council, Grain Legume Research Laboratory, Lilongwe:

  R. W. Gibbons, Agronomist and Team Leader.
  J. A. K Farrell, Entomologist.
  A. N. Adams, Entomologist.
  B. E. Bailey, Pathologist.

  Genetics; variety improvement and evaluation; breeding for resistance to cercospora leafspots and rosette virus; research to facilitate crossing of cultivated peanuts with wild Arachis species that are immune to cercospora leafspots and rosette virus; nature and control of insects and diseases.

KENYA

- EAAFRO, Nairobi:

  K. R. Bock, Virologist, Studies on rosette virus complex; has identified five separate viruses involved.

ASIA

ISRAEL

- Hebrew University of Jerusalem, Rehovot:

  Amram Ashri, Geneticist.
  A. Z. Joffe, Pathologist.

Genetics; variety development and evaluation; pod, seed, and soil mycoflora; studies of mycotoxins.

- Volcani Institute for Agricultural Research, Bet Dagan:

  Y. Alper, Agricultural Engineer.
  Elihu Goldin, Agronomist.
  Z. R. Frank, Pathologist.

  Variety improvement and evaluation; cultural practices; irrigation; nature and control of peanut diseases; seed inoculation; soil salinity; production machinery and procedures.

  J. Schiffmann, Legume inoculation.
  J. Shalhevet, Soil salinity research with peanuts.
  P. Reiniger, Soil salinity research with peanuts.
  D. Shimshi, Soil salinity research with peanuts.

INDIA

- Indian Council of Agricultural Research, All India Coordinated Research Project on Oilseeds (groundnuts, castor, sesamum):

  S. S. Rajan, Coordinator, IARI, New Delhi.

  Research carried out by numerous scientists at various State experiment stations and agricultural universities in genetics, breeding, variety evaluation, cultural practices; nature and control of diseases, nematodes and insects; mycotoxins.

- Punjab Agricultural University, Ludhiana:

  R. S. Sandhu, Agronomist.
  J. S. Chohan, Pathologist.

  Variety improvement and evaluation; disease resistance; nature and control of diseases and insects; cultural practices.

SOYBEANS

SOYBEANS 33/

WORLDWIDE PRODUCTION OF SOYBEANS

INHERENT PRODUCTION POTENTIAL PER HECTARE IN TERMS OF SEED, OIL, AND PROTEIN.

Seed

Seed yields in the major U. S. soybean producing states have averaged 2,150 kg./ha. in the Midwest and 1,750 kg./ha. in the South. Where good production practices are employed, these yields are doubled. Some good farmers consistently produce about 3,400 kg./ha. on several hundred hectares. A record yield of more than 7,300 kg./ha. has been reported.

Soybeans are usually second in importance to corn or cotton in a farming operation. They are sometimes planted late due to losses of an earlier planted alternate crop, or after a winter crop has been harvested. The good performance of soybeans under a wide range of management conditions is a major asset. However, since management conditions often require that soybeans be grown under less than optimum conditions, average performance on a state and national basis may be less reliable as an indicator of the inherent potential of soybeans than for other major crops.

Oil

Soybean oil comprises about 18 percent of the weight of the seed at 13 percent moisture content, with ranges from 16-20 percent among currently grown varieties. The production potential of oil, based on an average yield of 2,150 kg./ha., is 390 kg./ha. Based on the record yield of 7,300 kg./ha., this would be 1,300 kg./ha.

Protein

Protein content of currently grown varieties is approximately 35 percent of the seed weight at 13 percent moisture content.

33/ J. R. Wilcox, Soybean Investigations, Agricultural Research Service, U. S. Department of Agriculture, prepared this section on soybeans.

Experimental strains with good agronomic characteristics and 40 percent protein have been developed. However, these are usually lower yielding than currently grown varieties. Protein production, based on an average yield of 2,150 kg./ha., is 750 kg./ha., and would be 2,550 kg./ha., based on the record yield of 7,300 kg./ha.

QUALITY OF OIL AND PROTEIN, AND POTENTIAL USES

Nearly 92 percent of the domestic soybean oil production is used in shortening, cooking oils, and margarine. Classified as a semidrying oil, its iodine number is about 133, and industrial uses include paint, varnishes, resins, and plastics. About 80 percent of the fatty acids in the oil are unsaturated. The oil contains about 50 percent linoleic acid and 5-8 percent linolenic acid, which is suspected to contribute to instability and off-flavors.

Soybean meal has a high content of most of the amino acids essential for normal growth. The meal is slightly deficient in methionine, but contains a slight excess of lysine, the amino acid most often limiting in the cereals. Because of these characteristics, over 98 percent of the meal is used as a major protein supplement in livestock and poultry feeds. The meal does contain anti-nutritional factors which reduce its protein efficiency. Heating neutralizes these factors and significantly improves protein efficiency ratios. The amino acid content of soybean protein is compared with the FAO amino acid standard in Fig. 3.

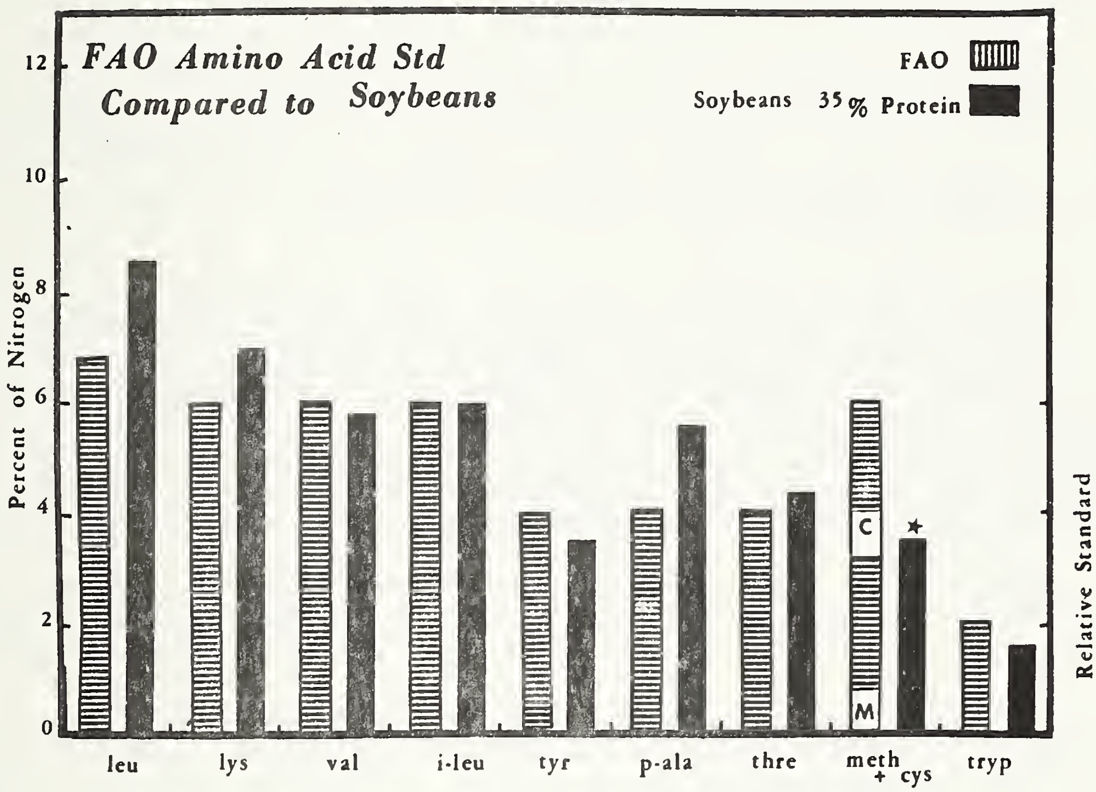
GROWTH CHARACTERISTICS AND TOLERANCES OF VARIOUS CONDITIONS

Soil Requirements

Soybeans are adapted to a wide range of soils, but do best on good, deep, well-drained soils. They will grow well and produce good yields on heavy clay soils that are somewhat poorly drained, but here, root rots are common and may limit yields. The optimum pH range for soybean growth is from 6.0-6.5. On more alkaline soils, micronutrient deficiencies, particularly iron and manganese, are common. On the more acid soils, manganese and aluminum toxicity may occur, and nitrogen and phosphorous availability is low.

Soybean varieties differ in their tolerance of salinity. Changes in performance with increased salinity ranging from 3.1-13.7 millimhos/cm. (0.05-0.25 percent NaCl on a dry soil basis) were: increased mortality, leaf necrosis, and accumulation of chloride in stems and leaves and decreased percent and rate of

Figure 3.--FAO amino acid standard compared to soybeans.



germination, green leaf color, dry stem production, seed yield, and quality. At 10.2 millimhos/cm., yield of Lee soybeans was reduced to approximately 60 percent of the control.

Soybeans respond to fertilization when soil test values for a particular element are low, except for nitrogen. A 3,400 kg./ha. soybean crop contains approximately 177 kg. of nitrogen, 21 kg. of phosphorous, and 59 kg. of potassium, which means these are minimal amounts which must be available to the plant to attain this yield.

Nitrogen is necessary for good plant growth; however, the soybean is able to obtain nitrogen from the air through the action of nitrogen-fixing bacteria, *Rhizobium japonicum*, in nodules on the roots. This bacterium is specific for soybeans and must be introduced into the soil if not already present. This is usually done by coating the seed just prior to planting with humus containing the bacteria. Research has shown little or no response to nitrogen fertilization where soybean roots are well nodulated.

Phosphorous and potassium are taken up by the soybean plant throughout the growing season, but the greatest demand is during pod filling. Approximately half of the P. and K. in mature seeds is translocated from other plant parts and the remaining half taken up from the soil during seed development. Varietal differences in sensitivity to phosphorous are known. There is little movement of phosphorous in the soil; therefore, adequate mixing in the root zone is required to ensure continued availability to the plant. Potassium leaches very little, except in sandy soils, is not accumulated to excess by the plant, and is inexpensive compared to other nutrients; therefore, this element can be raised to a high level in the soil to insure a continuing adequate supply.

Calcium is essential for normal plant growth as well as for effective nodulation of soybean seedlings. Since it is relatively immobile in the plant, a constant supply is required to maintain optimum growth. Rate of calcium uptake was reported to reach a peak 70-80 days after planting in one Midwest study. Magnesium is essential for normal soybean growth and yield responses from magnesium application on deficient soils have been reported. Pattern of uptake is similar to that of calcium. Both elements are commonly applied as limestone.

Sulfur is required for normal soybean growth, and deficiencies have been associated with synthesis of sulfur-containing amino acids. Sulfur uptake curves should parallel dry-matter curves since composition appears fairly constant. Soils generally have adequate sulfur for normal soybean growth.

Deficiencies of micronutrients are more widespread on soybeans than most field crops. Shortages of iron, manganese, molyb-

denum, and zinc have occurred in some areas of the United States. Varietal differences in sensitivity to iron, manganese, and aluminum have been reported. Serious micronutrient deficiencies have appeared on alkaline soils since the solubility, though not the total supply, of several nutrients goes down as pH goes up.

Water Requirements

A good crop of soybeans requires from 50-80 cm. of water. The period of germination is critical; excess moisture or prolonged drought may be injurious to the germinating seed. After the plant is established, it withstands short periods of drought and is not seriously retarded in growth or reduced in yield by a wet season. A sufficiently high and prolonged soil and plant stress affects virtually all aspects of soybean plant growth and metabolism. Relief of water stress is usually followed by a resumption of near normal growth and metabolism. Soybeans appear to be particularly sensitive to water stress when it occurs during the time of flowering and pod filling. Late July, August, or early September are, therefore, critical periods for maximum soybean yields in the United States. Average daily use of water by soybeans in July and August may run as high as 0.75 cm. under some conditions.

Time to Maturity, Daylength and Temperature Requirements

The soybean plant is photoperiod sensitive, which means that it makes the transition from vegetative to flowering stages in direct response to daylength. If the days are too long, flowering is delayed and plants produce excessive vegetative growth: flowering may even be prevented. If the days are too short, plants will flower within 30 days, before there is adequate vegetative growth to produce maximum yield. Since daylength is a function of latitude, soybean varieties are adapted as a full season crop to narrow belts of latitude. Maximum yields generally result from varieties which utilize the full growing season.

Soybean varieties are placed in 10 maturity groups, designated from 00 to VIII. Varieties in the 00 group are the earliest in maturity and will flower normally on daylengths of about 16 hours. They are adapted to the northern-most production areas of the United States and southern Canada, where they mature 105-102 days after planting. Varieties in group VIII are very late and will not flower normally on days longer than about 14 hours. They are adapted to the extreme southern United States, where they mature 165-180 days after planting. The sensitivity of soybeans to daylength restricts their potential use as a winter crop, except at very low latitudes.

Soybeans grow well in temperatures ranging from 21° to 38°C., providing adequate moisture is available. At the higher temperatures, moisture stress probably limits plant growth more than temperature per se. There is some evidence that varieties differ in their temperature requirements and that some are adapted to higher temperature conditions than others. The threshold temperature for germination is about 10°C. Emergence is more rapid at higher soil temperatures and seedlings can escape attack by soil organisms.

<u>Susceptibility to Diseases and Insects</u>

Soybeans are susceptible to numerous diseases; annual losses in the United States are estimated at 10 percent of the crop. Diseases recognized on soybeans and their causal organisms are listed below. An asterisk (*) indicates that varieties have been developed with moderate to complete resistance to the disease.

<u>Foliar Diseases</u>

Brown spot	<u>Septoria glycines</u>
*Frogeye leafspot	<u>Cercospora sojina</u>
*Downy mildew	<u>Peronospora manshurica</u>
*Target spot	<u>Corynespora cassiicola</u>
Alternaria leafspot	<u>Alternaria tenuissima</u>
Phyllosticta leafspot	<u>Phyllosticta sojiecola</u>
Black patch	<u>Rhizoctonia leguminicola</u>
Bacterial blight	<u>Pseudomonas glycinea</u>
*Bacterial pustule	<u>Xanthomonas phaseoli</u> var. <u>sojensis</u>
*Wildfire	<u>Pseudomonas tabaci</u>
Soybean rust	<u>Phakopsora pachyrhizi</u>

<u>Root and other Diseases</u>

Brown stem rot	<u>Cephalosporium gregatum</u>
*Phytophthora root rot	<u>Phytophthora magasperma</u> var. <u>sojae</u>
*Stem canker	<u>Diaporthe phaseolorum</u> var. <u>caulivora</u>

Pythium rot	*Pythium aphanidermatum*
Pythium rot	*Pythium debaryanum*
	Pythium ultimum
Rhizoctonia root rot	*Rhizoctonia solani*
Fusarium wilt and root rot	*Fusarium oxysporum*
	Fusarium orthoceras
Charcoal rot	*Macrophomina phaseoli*
Sclerotial blight	*Sclerotium rolfsii*
Sclerotinia stem rot	*Sclerotinia sclerotiorum*
Anthracnose	*Glomerella glycines*
	Colletotrichum truncatum
Phymatotrichum root rot	*Phymatotrichum omnivorum*

Seed Diseases

*Purple seed stain	*Cercospora kikuchii*
Pod and stem blight	*Diaporthe phaseolorum* var. *sojae*

Virus Diseases

*Soybean mosaic	Soybean mosaic virus
Bud blight	Tobacco ringspot virus
Yellow Mosaic	Bean yellow mosaic virus
Bean pod mottle	Bean pod mottle virus
Brazilian bud blight	Tobacco streak virus
Cowpea mosaic	Cowpea mosaic virus
Alfalfa mosaic	Alfalfa mosaic virus

In recent years insects have gained recognition as an important factor affecting soybean production in the United States. Insects have attacked the crop in the South in greater numbers

and varieties than previously experienced in midwestern and northern areas. Annual crop losses in the United States due to insects are 3 - 5 percent of the crop. Most of the major insect pests listed below can be controlled by use of appropriate insecticides.

Green cloverworm	*Plathypena scabra*
Soybean looper	*Pseudoplusia includens*
Velvetbean caterpillar	*Anticarsia gemmatalis*
Corn earworm	*Heliothis zea*
Fall army worm	*Spodoptera frugiperda*
Salt-marsh caterpillar	*Estigmena acrea*
Mexican bean beetle	*Epilachna varivestis*
Bean leaf beetle	*Ceratoma trifurcata*
Spotted cucumber beetle	*Diabrotica undecimpunctata howardi*
A thrips (no common name)	*Sericothrips variabilis*
Onion thrips	*Thrips tabaci*
Potato leafhopper	*Empoasca fabae*
Differential grasshopper	*Melanoplus differentialis*
American grasshopper	*Schistocerca americana*
Blister beetles	*Epicauta* spp.
Tarnished plant bug	*Lygus lineolaris*
Mites	*Acarina*
Lesser cornstalk borer	*Elasmopalpus lignosellus*
Granulate cutworm	*Feltia subterranea*
Seed-corn maggot	*Hylemya platura*
White grubs	*Phyllophaga* spp.
Grape colaspis	*Calaspis flavida*
Green stink bug	*Acrosternum hilare*

Southern green stink bug	*Nezara viridula*
Brown stink bug	*Euschistus servus*
Sweetpotato whitefly	*Bemesia tabaci*
Bihar hairy caterpillar	*Diacrisia obliqua*
Stem fly	*Melanagromyza phaseoli*
Girdle beetle	*Oberea brevis*

Plant parasitic nematodes are major pests limiting production in specific areas of the United States. Soybean yield losses due to nematodes have been estimated at about 10 percent of potential production by the Society of Nematologists. Major species causing losses are:

Root-knot nematodes	*Meliodogyne* spp.
Soybean cyst nematode	*Heterodera glycines*
Reniform nematode	*Rotylenchus reniformis*
Sting nematode	*Belonolaimus gracilis*

Resistant varieties have been highly successful in reducing losses to the first three nematodes, but there is no known source of resistance to the sting nematode. Also, races differing in host reaction have been observed. A fourth race of cyst nematode appeared in 1969. It is highly virulent on genotypes which are resistant to the three races known earlier. Suitable genetic resistance to the fourth race has not been found as yet.

Ectoparasitic nematodes associated with soybeans include *Pratylenchus* spp., *Paratylenchus* spp., *Tylenchorhynchus* spp., and *Helicotylenchus* spp. Although damage caused by these species has not been clearly demonstrated, they are suspected to reduce yields.

Weeds constitute a major hazard to successful soybean production. Annual losses are estimated at 16 percent of the production potential of the crop. Observations have shown yield reductions as high as 50 percent of the crop potential in individual fields. Early weed control is important because weeds, if left after midseason, seriously affect yields. Also, weeds are easier to control in the seedling stage than when well established. Mechanical weed control, including disking or harrowing before planting, rotary hoeing when soybean seedlings are in the unifoliolate stage to control seedling weeds prior to or at emergence, and shallow cultivation to control emerged weeds when soybeans are 20 cm. or

taller, is effective. Chemical weed control, including pre-plant or post-plant pre-emergence and post-emergence herbicides, is very effective. Different herbicides are formulated to control specific groups of weeds. Herbicide combinations or herbicide and mechanical cultivation are frequently used to achieve maxium weed control.

Plant pests, including weeds, reduce the yield potential of the United States soybean crop 15-20 percent. However, in a specific area or field, losses due to a particular pest may be extremely severe. Soybean cyst nematode populations in some fields prohibit growing any but resistant varieties. Phytophthora rot resistant varieties protect individual growers from periodic yield reductions which would prevent profitable soybean cultivation. Where moisture conditions restrict use of herbicides or prevent timely cultivations, weeds can drastically reduce yields. These effects may appear as minor reductions in the average national yield, but will have a devastating effect on the individual farmer who depends upon soybeans for his livelihood.

Special Harvesting, Storage, Processing Problems, etc.

Soybeans must be harvested as soon as possible after they mature to avoid shattering losses and seed deterioration due to diseases. Combining may be done at about 17 percent moisture; below 13 percent moisture, shattering and seed cracking occur during combining.

Because soybeans are enclosed in above-ground pods, they are less subject to attack by aflatoxin producing molds such as *Aspergillis flavus* than are peanuts, which are borne underground. After harvest, soybeans may be as subject to attack by fungi as other crop seeds, and must be protected accordingly. Soybeans should be stored in clean, dry bins, at a moisture content not to exceed 13 percent. At this moisture level, they will keep for a year or more without deterioration. If the moisture content is below 12 percent, germination will stay good into the second year. In the southern United States, moisture contents should be 1-2 percent below this to maintain good seed quality.

Large quantities (20,000-55,000 metric tons) of soybeans have been successfully stored temporarily in the open on a paved foundation with wood or masonry side walls. Beans are put into the storage area at a moisture content of 13 percent or less, then covered with a polyethylene sheet. Soybeans stored in this way in Indiana from October through February have not shown any signs of deterioration.

There are no unusual problems in extracting oil and producing meal from soybeans in a modern processing plant. However, major

impediments to the development of a successful soybean industry are the costs of processing plants and a transportation system to move soybeans from the production areas to the processing plant. Modern solvent extraction plants require a large capital investment and are relatively inflexible for other uses. Processing plants with an annual capacity of 150,000 metric tons require a capital investment of about $5 million; with an annual capacity of 300,000 metric tons, about $6 million; and with an annual capacity of 500,000 metric tons, about $8 million. Efficient plant operation requires an adequate supply of oilseeds for continuous operation. Other oilseeds such as cottonseed, can be processed in these plants for most efficient use of the facility. An effective transportation system capable of handling large quantities of oilseeds is essential to keep plants operating efficiently.

WEST PAKISTAN ENVIRONMENT AND CLIMATIC ANALOGS

SOIL

West Pakistan is situated between 23°30' and 36°45'N. latitude and 61° and 75°30' E. longitude. The country occupies part of the Indo-Gangetic Syncline, once an inland arm of the sea and now an immense alluvial plain. As in most extensive alluvial plains, the soils are, for the most part, sandy loams. But they show considerable local variability, from patches of almost pure sand to sandy loams, clay loams and even areas of very heavy clays. The soils are alkaline, generally saline to heavily saline, and waterlogging is a common problem in the flood plains of the major rivers. About 70 percent of the cropland is affected by waterlogging or salinity, 40 percent severely so.

WATER REGIME

The arable land of West Pakistan is concentrated in the floodplains of the Indus, Chenab, and Sutlej Rivers. Of the 80 million hectares in West Pakistan, 17 million are under cultivation. About 12 million of these are irrigated and approximately 2 million are double cropped. Major summer (Kharif) crops include cotton, rice, maize, and millet. Major winter (Rabi) crops include wheat, grain, and oil seeds, including rape and mustard.

WEATHER

Rainfall for the entire country averages less than 13 cm. annually, but does increase from south to north. Thornthwaites

moisture index, which is based primarily on plant requirements, is -40 to -60, indicating a severe moisture deficit. Annual and seasonal rainfall for representative locations in the country are tabulated below.

Table 18.--West Pakistan: Annual and seasonal rainfall, selected locations.

Location	Rainfall		
	Annual	Kharif Summer	Rabi Winter
	Centimeters		
Hyderabad	18.0	10.4	7.6
Rahemjar Khan	11.0	10.8	0.2
Lahore	47.8	31.4	16.4
Lyallpur	48.8	30.5	18.3
Peshawar	37.0	12.7	24.3

The mean monthly temperatures are summarized below for several locations.

Table 19.--West Pakistan: Mean monthly temperatures, selected locations.

Month	Mean Monthly Temperature			
	Hyderabad	Rahemajar Khan	Lahore	Peshawar
	Degrees Centigrade			
January	18	18	12	13
February	21	16	16	16
March	27	22	20	23
April	31	24	27	27
May	34	31	31	32
June	34	33	34	34
July	33	32	32	32
August	32	32	31	32
September	31	30	30	31
October	30	28	26	27
November	24	19	18	19
December	21	16	14	15

The warmest month is June and the coldest are December and January. For 6 to 8 months, the mean monthly temperature is 27°C. or above. Daytime highs of 41-46°C. during the summer months are common. Skies are generally clear, but frequently cloudy during periods from November to March. The summer or Kharif season is from April through September, and the winter or Rabi season from October through March.

Since soybeans are photoperiod sensitive and this is the major factor determining adaptation of varieties to a given area, the hours of daylight at latitudes 25°, 30°, and 35° are tabulated below:

Table 20.--West Pakistan: Hours of daylight.

Latitude	Hours of daylight (Hours:Minutes) 20th day of Month					
	Feb	Apr.	June	Aug.	Oct.	Dec.
25°	12:15	13:35	14:35	13:40	13:25	11:25
30°	12:05	13:50	15:00	13:50	12:20	11:10
35°	12:05	14:15	15:40	14:10	12:20	10:55

INSECTS, DISEASES, AND OTHER PESTS

Plant pests in West Pakistan include those normally associated with the major crops grown. Root rots occur in the heavy, water-logged soils. In the Sind, *Macrophomina phaseoli* has caused post-emergence damping off and root and stem rot of soybeans. In northern India, virus yellows of soybeans is fairly severe and could be expected to infect soybeans in West Pakistan. Other foliar diseases have not been noticeably severe in Northern India.

Insects are a common and severe problem on many crops in West Pakistan. Hairy caterpillars and sucking insects have damaged variety trials of soybeans.

There are over 30 insects which have been observed on soybeans in northern India. Five species have caused considerable damage and could be expected to attack soybeans in West Pakistan. The southern green stink bug, *Nezara viridula*, is quite abundant and attacks the plants during the latter part of the growing season. The white fly, *Bemisia tabaci*, is common and believed to be the vector for the virus yellows disease. Both wild and cultivated plant species harbor the virus. There are periodic outbreaks of

the Bihar hairy caterpillar, Diacrisia obliqua, which cause extensive damage to soybeans. The stem fly, Melanagromyza phaseoli, is ubiquitous and 1-5 larvae per soybean stem are common. When larger numbers attack the plants, they can cause extensive damage. The girdle beetle, Oberea brevis, can be very destructive on soybeans, although the incidence of this insect is usually low. The beetle lays eggs on the leaf petiole, the larvae bore into the stem and girdle it at the base from the inside, and winds break over the girdled plant. Damage amounting to 15-20 percent of the soybean crop has been observed.

AVAILABILITY OF ADAPTED OR USEFUL GERM PLASM

Soybeans adapted to the latitude of West Pakistan include the varieties Hill, Dare, and York in maturity group V; Hood, Lee 68, and Davis in maturity group VI; Bragg, Semmes, and Jackson in maturity group VII; and Hampton, Hardee, and Improved Pelican in maturity group VIII. Certain of these varieties are resistant to major diseases and to the cyst nematode. Varieties in these maturity groups perform best when planting is delayed until a day length of 14.5 hours occurs. On this basis in the south, at latitude 25° N, the best time for planting should be June 10 - July 10; in the central region, at latitude 31° N, May 15 - June 15; and in the north, at latitude 34° N, April 10 - May 30.

IMPLICATIONS FOR YIELDS

Cultural studies with soybeans have been carried out in various areas of West Pakistan. In the Hyderabad region, yields of 1,100-2,000 kg./ha. were obtained with 15 cm. pre-plant irrigation and 60-70 cm. of water applied in six and seven irrigations of 8 cm. each during the growing season. Maximum yields of 3,300 kg./ha. with Hampton 266 and 3,000 kg./ha. with Improved Pelican have been reported from the Hyderabad district. Planting date studies have shown June 15 to result in the best yields of 2,000 kg./ha.

Soybean cultural studies were conducted in the Peshawar region of West Pakistan in 1965 and 1966. April to June sowings at Mensehra and Tarnab and July sowing at D.I. Khan resulted in maximum yields of 1000 kg./ha.

Variety trials were planted at Mansehra June 1, at Tarnab June 6, and at D.I. Khan June 23, 1965. Plots were harvested October 10 and November 11 at Mansehra, October 23 - November 7 at Tarnab, and November 6 at D.I. Khan. Lee and Bragg produced maximum yields of 2,300 and 2,600 kg./ha. at Mansehra; Bienville and Mothi, 1,200 and 1,100 kg./ha. at Tarnab; Roanoke, and Bienville, 1,300 and 1,000 kg./ha. at D.I. Khan. Yields at D.I. Khan were

low due to poor germination. In row spacing studies, maximum yields of 1,100 and 1,500 kg./ha. were obtained from rows 30 cm. apart at Mansehra and Tarnab in 1965 and 1966.

A climatic analog to West Pakistan, where soybeans have been grown, would be the irrigated farm lands of the arid southwestern United States. Group VI varieties have been the most promising there. Several problems have been encountered in very arid regions. Varieties with adequate shattering resistance in humid climates have been unsatisfactory in arid climates of the western United States. Salt and nutritional problems have occurred. Abel, summarizing studies in the Imperial Valley of California (lat. about 33°, annual precipitation 8 cm., elevation -30 m.) reported that soils containing over 5 millimhos of salt cannot be expected to give good soybean growth.

Extensive tests of soybeans have been made in San Joaquin Valley of California (lat. about 36°, precipitation about 18 cm., elevation about 130 m.). Major problems with boron toxicity have been experienced in the San Joaquin Valley. Lodging has been more severe than in established soybean production areas. Yields obtained with current commercial varieties and advanced breeding lines from programs in humid areas have been disappointing, usually less than 2,000 kg./ha. The principal deterrents to higher yields are thought to be lodging, shattering, spider mite damage, and boron toxicity.

Soybeans are well established in the High Plains of Texas (lat. about 33°, precipitation about 46 cm., elevation about 1,000 m.). No unusual problems have been encountered. Irrigation is, of course, required here, as in California.

IMPLICATION FOR MULTIPLE CROPPING SYSTEM

Double cropping, the practice of sowing a crop of soybeans following another crop, usually small grains, is done in some areas of the southern and southeastern United States. To obtain nearly full production of each crop, it is essential that each be harvested as soon as it is mature and the other planted immediately. The success of late-planted soybeans is dependent upon having enough moisture to favor rapid germination and growth.

Double cropping in West Pakistan is already a common practice in some areas, and it appears that soybeans would be well adapted to such a system. Irrigation is required to successfully cultivate the crop, so the problem of adequate moisture for rapid germination and growth could easily be overcome. However, day lengths in the winter, or Rabi, season are always short enough to promote early flowering after minimum vegetative growth. For this reason,

currently available varieties would probably be best adapted to summer, or Kharif, season cultivation. Varieties might be developed that would produce adequate yields under cultural systems during the winter season.

STATUS OF RESEARCH

Soybeans have had more research effort than any other food legume crop. A heavy concentration of research has been in the United States and Canada. Research has also been carried on in Brazil, Colombia, Mexico, El Salvador, Honduras, India, Indonesia, Japan, and the Philippines.

IN THE UNITED STATES

The major objective of current breeding programs is to develop high-yielding varieties with good agronomic characteristics such as lodging resistance and suitable maturity for the various production areas. A search is underway for strains with low linolenic acid content (less than 2 percent) so this character can be incorporated into varieties. Because of increased demands for protein, the development of varieties with 40-45 percent protein has become an important breeding objective. An inverse relationship between percent protein and both yield and percent oil has complicated the development of high-protein strains with good yield and oil content.

In an effort to find methods for increasing yields through breeding, scientists are now determining the effects of 1) changing plant morphology, including canopy structure, leaflet number and shape, and stem determinancy, and 2) altering the duration of the flowering and pod-filling periods. Genetic studies are increasingly directed toward the control of physiological characteristics of the plant, such as enzymes differing in peroxidase activity.

Research is underway on interspecific hybridization in soybeans and the development of aneuploid series to associate specific characteristics with specific chromosomes. Linkage studies have already identified six linkage groups.

Physiological research includes determining the pattern of nutrient uptake and translocation in the soybean plant throughout the growing season. Research is underway on the biochemistry of photosynthesis, including external effects on photosynthesis such as water stress and light intensity. Leaf anatomy and its effect on the rate of photosynthesis is likewise being evaluated. Varietal

differences in leaf thickness have been found which are associated with different rates of photosynthesis. The biochemistry of lipid and protein synthesis in the soybean plant is being determined also.

Research is directed toward reducing the effects of plant pests on soybeans. Resistance to brown stem rot caused by *Cephalosporium gregatum* is being incorporated into high-yielding strains with resistance to other major soybean diseases. Sources of resistance to diseases affecting seed quality, such as purple seed strain, pod and stem blight, and soybean mosaic virus, have been identified, and the genetics of resistance is being studied as new disease-resistant strains are developed. Resistance to the soybean cyst nematode is being transferred to northern soybean varieties to combat the northward movement of the nematode. A search is underway for resistance to the fourth race of cyst nematode, a recently identified race virulent on varieties resistant to earlier races. The effects of nematicides are being evaluated as a method of nematode control.

Considerable research is underway on symbiotic relationships with the soybean plant. Different strains of *Rhizobium japonicum* have been identified and their efficiency in fixing nitrogen and their interactions with different soybean genotypes are being evaluated. Methods of altering the population of *R. japonicum* in the soil and inoculating fields with new strains is under study. The contribution of *R. japonicum* to the nitrogen metabolism of the soybean plant is being investigated.

The following is a partial listing of U. S. institutions, staff, and activities involved in soybean research:

ALABAMA

- Auburn University, Auburn:

    D. L. Thurlow, Agronomist, Soil fertility and production.

ARKANSAS

- University of Arkansas, Fayetteville:

    C. E. Caviness, Agronomist, Breeding varieties for southern regions, production research.
    C. Stutte, Physiologist, Nutrition and photosynthesis.

DELAWARE

- University of Delaware, Newark:

H. W. Crittenden, Pathologist, Breeding for resistance to diseases affecting seed quality.

FLORIDA

. University of Florida, Gainesville:

K. Hinson, Agronomist (USDA), Development of late maturing varieties for southern regions; development of high protein strains.

ILLINOIS

. Agricultural Research Service:

R. L. Cooper, Agronomist-in-Charge (USDA), Breeding varieties for northern region, production research.
R. L. Bernard, Geneticist (USDA), Breeding varieties for northern germplasm collection.
D. W. Chamberlain, Pathologist (USDA), Basis for disease resistance.
L. E. Gray, Pathologist (USDA), Effects of soil pathogens on soybeans.
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SUNFLOWER

WORLDWIDE PRODUCTION OF SUNFLOWERS

INHERENT PRODUCTION POTENTIAL PER ACRE

One bushel of sunflower seed weighs from 21 to 30 pounds. The current seed yield average of improved sunflower varieties, on a worldwide basis, is considered to be about 1,500 lbs./acre. Yield of improved hybrids is 20-25 percent higher than that of open-pollinated varieties. These estimates apply particularly to the Soviet Union, the largest sunflower producing country. Yield averages of Russian and American varieties grown at several locations throughout the United States are given in Table 21; yield averages on an American experimental hybrid and four open-pollinated commercial varieties are shown in Table 22. Record yields of 4,000 lbs./ acre are possible under experimental conditions. In the United States, Canada, France, and Romania, the recent finding of fertility-restoring genes that can be incorporated into new hybrids would most likely increase yields.

Seed of oil types contains around 45 percent oil, 25 percent hull, and 30 percent meal. After oil extraction, the meal contains 40 percent protein and 5-8 percent fat. The amino acid profile of the sunflower protein is complete, although lysine is low. On the basis of a worldwide seed yield of 1,500 lbs./acre, these data would be converted to 675 lbs./ acre of oil, 375 lbs./acre of hulls, 450 lbs./acre of meal, 186 lbs./acre of protein in the meal, and 22-36 lbs./acre of fat in the meal.

Oil content has been increased during the last 30 years from 38 percent to the present 50-52 percent in the dry seed. Recent Romanian hybrids derived from the high-oil content Russian VNIIMK 8931 contain 52.2 percent. In general there is an inverse correlation between oil content and protein content; high-oil types are low in protein. Sunflowers may be used as a silage crop. Under irrigation, silage yields are 20-35 tons/acre.

QUALITY OF OIL AND MEAL, AND POTENTIAL USES

Sunflower oil is a stable semidrying oil with iodine value of 135. Prolonged temperatures above 60°C. cause deterioration. The

34/ R. G. Orellana, Research Plant Pathologist, Oilseed and Industrial Crops Research Branch, Agriculture Research Service, U.S. Department of Agriculture, prepared this discussion on sunflowers.

Table 21.--Comparative yields[1/] of sunflower varieties and hybrids grown in the United States in 1966.

Type	Means obtained at 13 locations	Means obtained at 10 locations		
	Seed yield	Oil	Oil/acre[2/]	Meal[3/]
	Pounds/acre	Percent	Pounds	Pounds/Acre
Peredovik	1188	43.2	513.2	380
VNIIMK 8931	1241	44.9	557.2	372
Armavirec	917	42.1	386.1	303
Kubanec	1026	39.1	401.2	359
Vostok	1271	44.6	566.9	381
Mingren	1208	27.4	331.0	580
Commander	1093	28.6	312.6	514
Arrowhead	1204	31.0	373.2	530
Graystripe	1100	25.5	280.5	539
Manchurian	1509	24.4	368.2	754
Lyng-Manchurian 26	1900	27.9	530.1	893
LyngHyb. 1	2019	28.9	583.5	909
HO 1	1724	43.9	756.8	517

1/ From U.S. Regional Sunflower Yield Tests, USDA and Texas Agricultural Experiment Station cooperating.

2/ Calculated values.

3/ Calculated values.

Table 22.--Comparative yields[1/] of an experimental hybrid sunflower and open-pollinated varieties grown in the Red River Valley in the United States.

	Seed yield	Oil	Oil[2/]	Meal[3/]
	Pounds/acre	Percent	Pounds/acre	Pounds/acre
P-21 mX HA 60	1940	41.4	803.2	640
Peredovik	1733	47.3	819.7	485
VNIIMK 8931	1033	46.1	476.2	300
Smena	1494	46.3	691.7	433
Armavirec	1198	42.6	510.3	395

1/ From release of parental lines for production of hybrids, USDA and Texas Agricultural Experiment Station cooperating.

2/ Calculated values.

3/ Calculated values.

fatty acid composition of sunflower oil is the following: Palmitic, 6.9 percent; stearic, 5.6 percent; oleic, 26.5 percent; and linoleic, 61.1 percent. Linolenic acid occurs only in traces.

Sunflower oil is the chief edible oil in the Soviet Union and Eastern Europe and the main ingredient, after it is hydrogenated, in margarine and shortening in many countries in the area. It is also used as salad oil due to its similarity to olive and corn oil. Recently sunflower oil is being used in the paint and soap industries. In the United States, on an experimental basis, sunflower oil has been used as a replacement of petroleum oil in pesticide sprays. The use of sunflower oil in the potato chip industry is increasing.

Sunflower meal (Figure 4) is comparable to soybean and peanut meal. Because of its low fiber content and good digestibility, sunflower meal is used in animal feeds. Dehulled and roasted seed is packaged for human consumption as sunflower nuts. Sunflower protein is also used in the food industry as defatted flour for breakfast foods and bakery products, protein-type beverages, and meat analogs. "Halva," made from dehulled, crushed seed, sweetened and sometimes flavored with cocoa, is used in Eastern Europe and the Middle East for its high nutritive and caloric value.

Sunflower seed hulls are used in the preparation of furfural, and as a source of bulk in ruminant rations. Pectin is said to be produced from sunflower plant tissue in the Soviet Union.

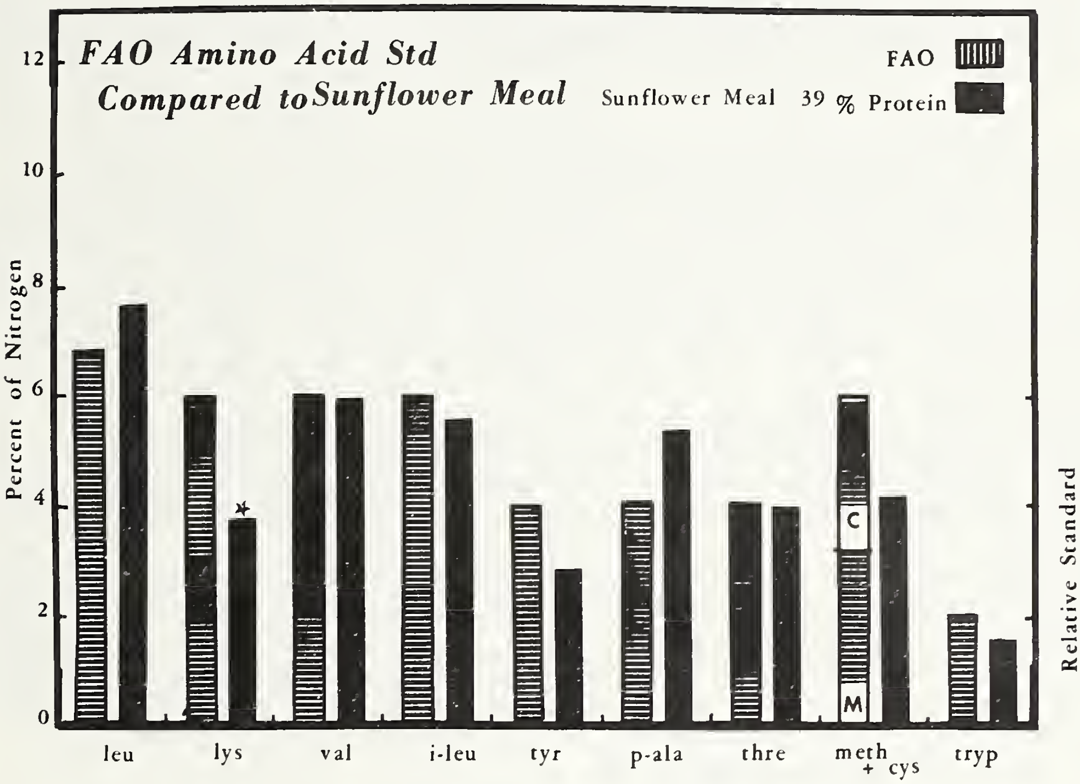
GROWTH CHARACTERISTICS AND TOLERANCE TO VARIOUS CONDITIONS

Soil and Water Requirements

The crop yields best in fertile soils with good drainage in areas with 20-30 inches of annual rainfall. Such areas are found in the Red River Valley in Minnesota and North Dakota in the United States, the Krasnodar region in the Soviet Union, the fertile plains in Romania, etc. Sunflowers can be grown in soils suitable for corn and cotton. They have been grown successfully with about 30 inches of rainfall in Argentina and with about 10 inches in Iran. Sunflowers are not well adapted, however, to heavy, waterlogged soils. Sandy loan soils of pH around 6.5 are better suited for sunflowers than acid or alkaline soils.

Sunflowers respond to natural soil fertility better than to chemical fertilizers, under both dry-land cultivation and irrigation. However, the crop would respond well to chemical fertilization when essential nutrients are in deficit. Fertilizer trials on sunflowers have been conducted at the Northwestern Experiment Station at Crookston, Minnesota, for several years, and are continuing. Further field trials are still necessary before final

Figure 4.--FAO amino acid standard compared to sunflower meal.



conclusions concerning the nutritional requirements of this crop can be made.

The seed is generally planted in rows. Row spacing of 36 inches with plants 6-8 inches apart in the row is common practice. The amount of seed required varies, but is about 4-8 lbs./acre.

Sunflowers need to be irrigated when grown in arid or semi-arid areas or when long periods of drouth prevail. Irrigation water is applied by canal or pipes. Flood irrigation is not used for sunflower cultivation. It is estimated that the crop requires between 18 to 25 inches of water during the growing cycle. Sunflowers are furrowed or subirrigated, but irrigation after heads are formed is avoided because plants may fall. Soil moisture is indispensable around planting time for rapid seed germination and good planting stands. The seed may be planted earlier than corn, as light frost generally does not kill the seedlings. When the growing season is relatively long, planting can be delayed 2 to 3 weeks after that of corn. To assure good physiological development and seed maturity, early planting is usually recommended.

Experience is lacking in respect to sunflower cultivation in areas with salinization problems. Because Compositae related to sunflower are salt-tolerant, it may be inferred that the sunflower is somewhat tolerant, within limits, to soil and water salinity. Whether or not there is differential tolerance to salt among sunflower varieties and whether salt would affect yield and seed quality is now known.

Time to Maturity, Daylength, and Temperature Requirements

The sunflower requires from 100 to 150 days to mature. Early maturing varieties require 100-125 days; late-maturing varieties 125-150 days. Differences in susceptibility and resistance to disease in certain varieties is associated with daylength and light intensity, as has been observed under experimental conditions at the U.S. Department of Agriculture in Beltsville, Maryland. Although yields are influenced by photoperiodism and energy utilization, actual figures are not available for the sunflower.

Extremes of temperature interfere with normal sunflower cultivation. Plantings are sometimes damaged by early frosts at the onset of the fall season in the Red River Valley in the United States, so that the use of early-maturing varieties would be preferable. On the other hand, air temperatures above 32°C. may also damage the crop by promoting excessive loss of soil moisture by evaporation and plant transpiration. This situation may become critical under dryland cultivation and insufficient irrigation.

Susceptibility to Diseases and Insects

Sunflowers are attacked by several diseases and insect pests. The three major diseases are rust, *Verticillium* wilt, and downy mildew. The main insect pest is *Homocosoma* head moth. There are no serious bacterial or viral diseases that could be considered at this time to be limiting factors. There is, however, a parasitic plant, *Orobanche*, which causes substantial damage.

Rust, caused by *Puccinia helianthi*, an autoecious, obligate fungus pathogen, is the most common worldwide disease of the sunflower. Yields of susceptible varieties are reduced as much as 50 percent. The rust fungus is a variable organism which includes several virulent races and has the capacity to evolve new races endangering new sunflower varieties and strains. Varieties of sunflowers resistant to the known races are presently available.

Verticillium wilt caused by *V. albo-atrum* and/or *V. dahliae* is a highly destructive disease. Although *Verticillium* is not as widespread as rust, the fungus is endemic and, therefore, difficult to eradicate from infested soils. Symptoms of *Verticillium* wilt are easily confused with those ofother diseases, and often the disease remains unrecognized. Losses caused by this wilt are high because all infected plants die. Although isolates of *Verticillium* from sunflowers have a high degree of pathogenic specificity to sunflowers, susceptible varieties are infected by *Verticillium* from other hosts.

Downy mildew is caused by *Plasmopara halstedii*, known also in the Soviet Union as *P. Helianthi*. Downy mildew is a very destructive disease, particularly during wet seasons in areas where the soil is saturated and where crop rotation has not been a regular practice. Under these conditions, losses of 50-60 percent are common in North Dakota and Minnesota and in Eastern European countries. Fortunately, genes for resistance to this disease are available and are presently being incorporated in new sunflower hybrids. Other diseases, such as charcoal rot (*Macrophomina phaseoli*), root and stem rot (*Sclerotinia sclerotiorum*), and *Septoria* leaf spot (*Septoria helianthi*) undoubtedly cause reduction in yield; however, estimates of yield losses are difficult to make.

Homoeosoma ellectellum, the species of sunflower moth in the Western Hemisphere, is the factor limiting sunflower production in the southern part of the United States. The moth lays eggs on the head at flowering time and later overwinters on wild and cultivated sunflowers, other species, and in the soil. Differences in suceptibility to the insect have been observed among sunflowers of Russian genotypic background. A combination of resistant or tolerant varieties, date of planting, chemical control, and sanitation may be required for complete control.

Homoeosoma nebulellum is the species of head moth prevalent in the Soviet Union and Eastern Europe and, like *H. ellectellum*, causes significant losses in yield. Control of this pest is reported to have been achieved by the development of resistant varieties possessing the so-called armored layer on the seed which the larva cannot overcome. There is no such morphological defense in the sunflower against *H. ellectellum*. There are several other insect pests of the sunflower, such as the carrot beetle (*Bothynus gibbosus*) that destroys the emerging seedling, stem cutting insects, etc., but none of these is as destructive as the head moth.

Broom rape or *Orobanche cumana* is a destructive and prolific parasitic plant of the cultivated sunflower in the Soviet Union, Eastern Europe, and in Turkey. Apparently this species of *Orobanche* is not present in the Western Hemisphere. The parasitic plant invades the root system of the growing sunflower and competes with it for nourishment. *Orobanche* produces minute seeds that remain viable in the soil for a very long time. It was reported that *Xanthium* sp., a wild plant related to the sunflower, is a host of broom rape in Romania. Control of the parasite may be achieved by the use of tolerant sunflower varieties, soil disinfection, and regular crop rotation.

Sunflowers are harvested with combines like those used for cereals. For sunflowers, however, the combine must be fitted with a special header attachment. In the United States there are several header types, and a new type of sunflower harvester, developed by the Melrose Clark Equipment Company, has been tested with excellent results. To reduce harvesting losses, combining on sunflowers must be done when the plants are fully mature but before the seeds are shattered due to over-drying. The sunflower seed should be stored at a moisture content of not over 12 percent. To regulate and obtain optimum moisture content in the seed, processing plants need to have special drying equipment. Present grade standards for sunflower seed require that Grade 1 seed should contain not over 10 percent moisture and Grades 2 and 3 not over 12-14 percent moisture.

Sunflower seed is processed in accordance with the seed type involved. High-oil types are extracted by either the "extractor" method or the "expeller" method. The amount of oil left in the residue depends on the efficiency of the method used. Non-oil types are processed for meal by conventional fractionation equipment.

WEST PAKISTAN ENVIRONMENT AND CLIMATIC ANALOGS

West Pakistan occupies part of the Indo-Gangetic syncline, a depression filled with sediments and now a vast alluvial plain. The area known as Indus Plains, 900 miles long and as much as 400 miles wide, is the most extensive continuous zone of regularly cultivated land in the country. Most of the sediment that underlies the plains is water-saturated to within a few feet of the land surface. The Punjab region, located in the northern part of the Indus Plains, is drained by five rivers which converge in a fan-shaped pattern to form the main Indus River that runs south through the Sind region and to the Arabian Sea.

SOILS

The large soil groups represented in the Indus Plains are red-brown soils in the north and red and gray desert soils (Sierosem) in the south. Textures of these soils have been grouped into five classes, which include sandy, sandy loam, silt loam, sandy clay loams, and clays. These soils are mostly alluvial in origin and calcareous in nature, low in organic matter and in available N and P but productive when irrigated. In some soils, movement of Ca ions has resulted in precipitation of calcium carbonate. Saline and alkaline soils have developed both under natural conditions and as the result of irrigation, especially when ground water lies near the surface. These soils have been somewhat modified by tillage and irrigation.

Climatic and soil analogs of West Pakistan are those found in most arid and semi-arid regions. Such analogs are in Israel, Egypt, the Middle East, North Africa, India, Spain, Mexico, Peru, and the Imperial Valley in the United States.

WATER REGIME

The principal natural resource of West Pakistan is the ground-water reservoir underlying the Punjab region. About 2 billion acre-feet of fresh water is stored in the alluvial deposits of the region. Fresh ground water contains from 500 to 1,000 p.p.m. of total dissolved solids. Saline ground water with 4,000 to more than 30,000 p.p.m. occurs in the lower Punjab and parts of the lower Bahawalpur area to the East. The solution of minerals by nearly stagnant ground water in the alluvial deposit and evaporation from the water table may explain the origin of the saline ground water in the Punjab. Ground water in Sind contains about 100,000 p.p.m. or more of dissolved solids. If salinity could be eliminated, more than 90 percent of the area would be suitable for irrigation farming. In general, seepage

from rivers and irrigation canals produces water logging and soil salinization in much of the Indus Plains in West Pakistan.

Total water diverted for agricultural use is about 60 million acre-feet per year. In Bahawalpur about 3.2 million acres are irrigable by canal irrigation. All throughout the Indus Plains there is a great deal of run-off in summer which is wasted to the sea. Salinity is encroaching upon new lands at a rate of about 100,000 acres per year, of which about one-half goes out of production due to inadequate supply of irrigation. Experience related to tolerance of sunflowers to saline soil is extremely limited. Trial plantings in soils of known levels of salt content would be useful to determine the tolerance of this crop to salinity.

WEATHER

Annual and seasonal rainfall and mean monthly temperature for various regions in West Pakistan are given in Tables 23 and 24. In the Punjab region, rainfall ranges from 24 to more than

Table 23.--West Pakistan: Annual and seasonal rainfall, selected locations.

Location	Rainfall		
	Annual	Kharif Summer	Rabi Winter
	Centimeters		
Hyderabad	18.8	10.4	7.6
Rahimjar Khan	11.0	10.8	0.2
Lahore	47.8	31.4	16.4
Lyallpur	48.8	30.5	18.3
Peshawar	37.0	12.7	24.3

Table 24.--West Pakistan: Mean monthly temperatures, selected locations.

Month	Mean Monthly Temperature			
	Hyderabad	Rahemajar Khan	Lahore	Peshawar
	Degrees centigrade			
January	18	18	12	13
February	21	16	16	16
March	27	22	20	23
April	31	24	27	27
May	34	31	31	32
June	34	33	34	34
July	33	32	32	32
August	32	32	31	32
September	31	30	30	31
October	30	28	26	27
November	24	19	18	19
December	21	16	14	15

30 inches near the Himalayas foothills, to about 14 inches at Thal and Bari, and to less than 6 inches in the southern Punjab plain. Rainfall in Sind and Hyderabad is less than 6 inches, but humidity is high. The warmest months are May and June, with record temperatures of 120° F. Frost does not occur in the Punjab or farther to the south.

Crops sown when the rains start in late spring or early summer are harvested in late summer or early fall and are called "Kharif" (April-October); crops sown in fall and harvested the following spring (October-April) are "Rabi" crops; the southern Sind is sown to "Kharif" crops exclusively. Sometimes "Rabi" and "Kharif" crops are grown on the same land with a catch crop in between, which gives rise to two or three crop patterns a year. The climate in most of the Indus plains makes irrigation a prerequisite for intense agriculture.

Trials at Punjab, Hyderabad, and Peshawar have shown that sunflowers develop normally if planted as a "Kharif" crop. It is unlikely that late sunflower varieties would do as well as early varieties, or that sunflowers could be grown as a catch crop in a double crop pattern.

DISEASES AND INSECTS

Except for isolated reports of certain diseases and pests of sunflower in West Pakistan, a comprehensive disease survey of this crop is not available because sunflowers have not been and are not presently grown as an oilseed crop. If sunflowers were grown on a large scale, it is likely that this crop would be affected by most of the known diseases. Recent casual observations at sunflower trials in Hyderabad have indicated that a disease resembling charcoal rot and a "parasitic plant" were present. A parasitic plant known as broom rape (*orobanche cumana*) is a serious problem of sunflowers in Eastern Europe. The implication that diseases and insects would have on sunflowers in West Pakistan cannot be assessed on the basis of present available information. The head moth (*Homoeosoma*), if present in West Pakistan, would be a limiting factor. *Verticillium* wilt, downy mildew, and *Sclerotinia* would be also problems in wet soils. Charcoal rot could be of importance under low rainfall in warm soils.

AVAILABILITY OF ADAPTED OR USEFUL GERM PLASM

Sunflowers are not grown in West Pakistan in commercial scale and germ plasm is scarce. Trials of small local collections and the American variety HO 1 have been made in recent years on a limited scale at the following locations: Lyallpur and Lahore in the Punjab; Rahim Yar Than; Tandojan in the lower Sind; Hyderabad; Peshawar; and Quetta. The latter area is outside the Indus Plains. (Figure 5). Matlock reports that, of the local varieties BIRR, KIRR, a Lyallpur strain, and HO 1, only the latter was productive.

IMPLICATIONS FOR YIELD

Seed yields and oil content of sunflowers grown in the northern, central, and southern regions of West Pakistan have been estimated by Matlock as shown below.

As shown in Table 25, seed yields of 30 maunds/acre of sunflowers grown as a "Kharif" crop are encouraging. To obtain further information as to the potential of sunflowers as an oilseed

Figure 5.--West Pakistan: Location of sunflower trials.

Table 25.--Estimated seed yield, oil content, and calculated oil yield of sunflowers in West Pakistan trials.

Mean seed yield 2/			Oil	Mean oil yield		
North	Central	South		North	Central	South
------Maunds per acre-----			Percent	---Maunds per acre-----		
14.0	30.0	25.0	37.0	5.2	11.1	9.2

1/ From "A Study of the Potential for Increased Oilseed Production in West Pakistan" by R. S. Matlock, U.S. Agency for International Development, 1967.

2/ A unit of weight in India varying from 24.7 to 82.28 pounds, but usually the latter.

crop for Pakistan, Matlock suggested that trials with several improved varieties and the local variety Black Sayar be planted between July 1 and September 1 in the northern, central, and southern regions. Such trials should include early- and late-maturing, high-yield, and high-oil varieties as well as genotypes with resistance to rust, *Verticillium*, and downy mildew. Resistant genotypes from a given region may not be, however, resistant in another region, but would provide useful information.

IMPLICATION FOR MULTIPLE CROPPING SYSTEMS

Pakistan agriculturists have suggested that sunflowers would fit well in cultivation with or without supplemental irrigation. Dry land cultivation of sunflowers may be feasible in Peshawar

where the soil is fertile and rainfall is about 10 inches per year. In this area, however, sunflowers would be favored by irrigation. Sunflowers on regularly irrigated cropland may be raised in several areas in the Punjab, Peshawar, Sind, and Hyderabad, provided the land is level and well-drained. Suitable land for sunflowers may be found also in new areas brought into cultivation in Bahawalpur where fresh ground water for irrigation contains only about 5,000 p.p.m. of dissolved solutes.

The suitability of other regions, such as the Dera Ismail Khan, for sunflower cultivation has not been assessed. Data on water resources and ground water for irrigation in this region were published by the U.S. Geological Survey and AID in 1970.

Crop rotation is a recommended practice in sunflower cultivation in order to prevent build-up of harmful soil-borne pathogens. In West Pakistan, locally adapted leguminous crops could be used for rotation with sunflowers. Competition for land and irrigation would likely be felt, especially with crops grown on the basis of tradition rather than proper land use. Such a situation would change if sunflower cultivation is shown to be profitable.

Land forms, soils, and land use of West Pakistan were studied by the Water and Soils Investigation Division of West Pakistan in cooperation with Canada through the Colombo Plan in 1952-57. Systematic studies of the water resources, irrigation and related problems in West Pakistan were initiated in 1954 by WASID in cooperation with the U.S. Agency for International Development through the U.S. Geological Survey, and are being continued. This information is available in several publications and detailed maps, and would be very useful in future agricultural planning of West Pakistan. Procedures for diagnosis and reclamation of salt-affected soils have been developed by the U.S. Salinity Laboratory at Riverside, California, and are used in all parts of the world.

STATUS OF RESEARCH

IN THE UNITED STATES

Research on production and improvement of sunflowers was initiated about 7 years ago by the Oilseed and Industrial Crops Research Branch, Agriculture Research Service, U.S. Department of Agriculture, in cooperation with the Texas, Minnesota, and North Dakota Agricultural Experiment Stations, seed companies, and individual farmers. Sunflower production in the United States has increased, but is still small.

In 1968, three high-oil, rust-resistant lines suited for the production of hybrids were released. TAM CRD P-21 ms, the first genetic male sterile line released to the American seed grower, is also homozygous for dominant resistance to Verticillium wilt, as shown by means of controlled inoculation at the Plant Industry Station, Beltsville, Maryland. The other two released were TAM CRD HA 60 and TAM CRD HA 61. The hybrid P-21 ms X HA 60 yielded better than open-pollinated Russian varieties (Table 22). It is significant that hybrids involving HA 61-1 are resistant to downy mildew under natural conditions in Texas, and it may be possible to produce downy mildew resistant varieties.

The recent discovery of a fertility-restorer gene in an agronomically desirable and rust-resistant line will result in higher yield of hybrid sunflowers.

Little is known thus far about the general rust race distribution and virulence of existing races of this pathogen in the United States.

A study of downy mildew based on herbaria showed that the pathogen has a wide host distribution among wild and cultivated annual and perennial species of Helianthus. Whether some of these species are potential sources of resistance has not been fully investigated.

In a study of Verticillium wilt of sunflowers, it was found that pathogenicity among isolates from sunflower was nearly specific with respect to sunflowers. Susceptible varieties, however, can be infected by Verticillium from other hosts under certain rotation sequences.

With respect to charcoal rot disease, it was found that sunflowers varied in their field response to the disease. Early-maturing varieties were more susceptible than late varieties and certain late hybrids. The occurrence of resistant individual plants within segregating progenies suggests that charcoal rot resistant sunflowers can be developed.

Current work on sunflower head moth control is still limited. Certain insecticides, although effective, may interfere with pollination by bees and be toxic to personnel involved. Differences in susceptibility to moth attack, observed in certain sunflower genotypes, is promising.

The use of sunflower oil, meal and protein isolates is presently limited. Research on sunflower seed storage conducted at the University of Minnesota has shown that seed moisture above 12 percent would promote fungal contamination of the seed. Up to now, Aspergillus flavus and other aflatoxin producing microorganisms have not been found on stored sunflower seed.

The following people provide leadership in sunflower research in the United States:

. U.S. DEPARTMENT OF AGRICULTURE

M. L. Kinnan, Breeder, College Station, Texas.
R. G. Orellana, Plant Pathologist, Plant Industry Station, Beltsville, Maryland.
D. E. Zimmer, Plant Pathologist, Fargo, North Dakota.

. Oilseed Products Research Center, Texas A&M University:

C. M. Carter, Chemist, College Station, Texas.

. Texas Agricultural Experiment Station:

G. L. Teeter, Entomologist, College Station, Texas.

. University of California:

P. F. Knowles, Agronomist, Davis, California.

. University of Minnesota:

R. G. Robinson, Agronomist.
C. M. Christensen, Mycologist, St. Paul, Minnesota.
O. C. Soine, Soil Scientist, Crookston, Minnesota.

. University of North Dakota:

J. T. Schultz, Entomologist, Fargo, North Dakota.

Research on sunflowers is being initiated at various Experiment Stations in the southern states.

Background and detailed information on sunflower production on a worldwide basis is contained in papers listed in the following bibliographies:

"Sunflowers: A literature Survey," January, 1960-June, 1967, National Agricultural Library, Library List No. 95, U.S. Department of Agriculture, Beltsville, Maryland; and "Sunflower Diseases and Pests, A Selected Bibliographical List," 1969, Oilseed and Industrial Crops Research Branch, Agriculture Research Service, U.S. Department of Agriculture, Beltsville, Maryland.

IN PAKISTAN

Preliminary trials on adapatability, planting dates, and yield of sunflowers which have been conducted in West Pakistan suggest that sunflowers can be grown successfully as a "Kharif" crop in several regions. The most suitable planting date would vary with local conditions but, as suggested by Matlock, would be between July and September. The American variety HO 1 on a trial basis at the Ayub Research Institute in Hyderabad had a yield of 26.5 maunds/acre of seed having 39.2 percent oil and 22.0 percent protein. It matured in about 100 days and required six irrigations of 4 inches each. Information on diseases, insects, and/or other factors that may limit production, according to Matlock, is not sufficient to make definite recommendations. Uniform and more extensive trials seem to be needed.

ELSEWHERE

Soviet Union

Research on sunflowers, with emphasis on achieving high oil content, was initiated about 55 years ago and continues at the All-Union Research Institute for Oilseeds, Krasnodar. The current oil content of improved varieties like VNIIMK, Peredovik, Smena and Armavirsky is reported to be 48-50 percent of the dry seed, and higher oil contents are expected. These varieties are being used in crosses in several other countries to increase oil content of local sunflowers. Seed yields have also gone up, and the current average yield is estimated to be around 1,500 lbs./acre. Varieties with "multiple resistance" are reported to exist. The diseases referred to are downy mildew, rust, and Sclerotinia. Resistance to broom rape and head moth is apparently being incorporated in new varieties. Crossing with the rust-resistant Texas wild sunflower has provided resistance against this disease. Some of the rust-resistant varieties are susceptible to rust in North America, however.

Research personnel working with sunflowers at the All Union Institute of Oilseed Crops, include Galina Pustovoit, Breeder, A. Y. Panchenko, Plant Pathologist.

Romania

Sunflower research in Romania is centered at the Research Institute for Cereals and Technical Plants at Fundulea, Bucharest. Seed yield averages are 1,400-1,500 lbs./acre. Yields of 3,500 lbs./acre have been obtained under experimental conditions. The Institute has developed sunflowers of the "single" hybrid type with high yield, high oil content (52.2 percent) and uniformity.

in plant size. These hybrids are soon to enter large-scale production.

Romanian research personnel include V. Vranceanu and V. Vulpe, breeders, and Marina Narcomnicu, Plant Pathologist.

Canada

Research on sunflowers is centered at the Morden Experiment Station in Manitoba and concerns breeding for high yield, high oil content, and disease resistance. Pollen fertility restorers have also been identified here, as has been done in the United States, France, and Romania. Investigations also are under way on weed control. Research on diseases is also conducted at McGill University, Montreal.

Research personnel include E. D. Putt, Breeder, and his collaborators at the Morden Research Station and W. E. Sackston, Plant Pathologist at McGill University.

France

Research on sunflower improvement is underway at the "Station d' amelioration des Plantes" at Clermont-Ferrand. The main objectives are 1) to obtain resistance to lodging and to the fungus Botrytis and 2) to obtain higher yields of seed and oil. Cytoplasmic male sterility is the character used in producing hybrids.

Researcher at the Station d'Amelioration des Plantes is P. Leclercq, Breeder.

Argentina

Sunflower improvement work is conducted at the Estacion Experimental Pergamino.

Miscellaneous

Appreciable sunflower research is also conducted in various countries in western and eastern Europe.

COTTONSEED

COTTONSEED 35/

WORLDWIDE PRODUCTION OF COTTONSEED

INHERENT PRODUCTION POTENTIAL PER ACRE 36/

The cotton producing area of Pakistan is similar to the ecosystems of the Imperial Valley of California, the Nile Valley in Egypt, and to some extent, the cotton producing area of Israel. With modern production methods, the yields of Israel and the Imperial Valley approximate 3,600 pounds of seed cotton per acre. By contrast, the yields of Pakistan averaged 816 pounds per acre in 1969-70.

Assuming a potential production figure of 3,600 pounds of seed cotton per acre for Pakistan, an annual production increase of approximately 12 billion pounds could be expected from the 4.4 million acres planted.

A production increase of this magnitude would provide, annually, an additional 8 million bales of lint, 520 thousand tons of linters, 800 thousand tons of oil, and 800 thousand tons of protein. These figures are based on a 33 percent lint recovery and a linter, oil, and protein recovery from the seed of 13, 20, and 20 percent respectively. The assumption is made that modern ginning and seed processing machinery would be used.

Other seed-derived by-products of economic significance might include an annual increase of 200 million pounds of raffinose sugar and 1.6 million tons of seed hulls of potential use as ruminant feed or for soil amendment.

QUALITY OF OIL AND MEAL, AND POTENTIAL USES

Cottonseed Oil

Crude cottonseed oil is darker in color than soybean, peanut or corn oils. It is, however, easily bleached and refined, yielding a product equal or superior to the other oils. The stability with time of the refined products exceeds most other vegetable oils. It displays outstanding resistance to rancidity. When

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35/ B. M. Waddle, Cotton and Cordage Fibers Research Branch, Agriculture Research Service, U.S. Department of Agriculture, prepared this discussion on cottonseed.

36/ From references 1 to 6 listed on page 164.

deodorized, it maintains its flavor and odor remarkably well in comparison with competing oils. The oil is utilized for salad oils, hydrogenated shortenings, cooking oils, preparation of salad dressings, and margarine (Pakistanian Ghee). Useful by-products of the oil are soap stocks, lecithin, tocopherols, and a source of Vitamin E and edible anti-oxidants.

The useful by-products of oil extraction are cottonseed meal, seed coats or hulls, and linters (the fuzz remaining on the seed after ginning). The meal is by far the most important by-product.

Cottonseed Meal

Cottonseed meal, with residual oil remaining from the extraction process, contains approximately 50-55 percent protein, 20 percent carbohydrates, 7 percent minerals, 8 percent moisture, minor amounts of organic phosphorus and nitrogen, pronounced anti-oxidant properties from polyphenolic compounds, and the vitamins C, the B complex, and smaller amounts of A, D, E, and K. However, this varies widely, depending upon the extraction process used. Also, the amount of vitamin K is not sufficient to meet cattle needs entirely when cottonseed meal is used as the sole feed source.

The main use of cottonseed meal is cattle feed. The presence of the pigment, gossypol, makes the meal toxic to non-ruminant animals, including man, and, until recently, limited the meal's usefulness for other farm animals. When cottonseed is processed by the proper screw press extraction or prepress solvent extraction methods, however, gossypol is bound and the meal is suitable for feed for ruminant animals and poultry. Small quantities of purified cottonseed protein concentrate have in fact been used in bakery products for over 30 years in the United States.

Two recent developments offer promise of completely removing the hazard of gossypol and to open the way for the use of meal as a high-quality protein source for human nutrition. The first is the development of the liquid cyclone process which mechanically removes gossypol-containing glands from the meal. The second is the discovery of a glandless seed character that is genetically controlled. Glandless varieties of upland cotton have been developed. If they can be grown successfully, they would eliminate the need for the fractionation process mentioned above. Either of the above two breakthroughs permits the possibility of producing human-grade cottonseed flour and other edible products of high protein content.

Seed Hulls

Seed hulls are routinely added to animal feeds for roughage and are mostly disposed of in this manner. They contain cellulose, some carbohydrates, and lignin, but are little used as a source for these materials.

Linters

Linters, the fuzz remaining after ginning, are removed from the seed with equipment similar to the standard cotton gin stands, but with greater numbers of saws. Several runs or cuts are made on each batch of seed. The first cut yields up to 70 pounds per ton of seed, giving a fiber capable of being manufactured into felt, batting, surgical dressings, and low-grade textiles. Subsequent cuts are used in the manufacture of rayon, plastics, lacquers, explosives, and paper.

GROWTH CHARACTERISTICS AND TOLERANCE OF VARIOUS CONDITIONS

Soil Requirements

Cotton makes its best growth and yields on deep, well-drained, alluvial soils of loam to sandy-loam character. Clay soils are also acceptable up to percentages of clay where moisture penetration and aeration become marginal. Cotton will produce at an acceptable level within the soil pH ranges of 4.5 to 9.5, provided salinity or alkalinity at the higher pHs is not excessive. Cotton is considered relatively salt tolerant, with a tolerance about equal to that of rye, wheat, oats, and rice. It is more tolerant than barley, sugar beets, and rape. In terms of conductivity of a saturated extract from soil, it is in the tolerance range of 6-8 x 10^3 millimhos per centimeter at 25° C. During the growing season, an average-yielding cotton crop removes from the soil approximately 130 pounds of nitrogen, 30 pounds of phosphorus, 85 pounds of potassium, 94 pounds of calcium, and 26 pounds of magnesium on a per acre basis. Adequate but minor quantities of all the micro-nutrients are required. If the cotton stalks are returned to the soil, approximately 40 percent of these mineral nutrients will be returned at the end of the growing season. If the nutrients are not present in an available form in a given soil at the above levels, fertilizer practices to meet these requirements are a necessity for average production. (Soil requirements information is from references 7 and 8, page 164.)

Water Requirements

For the actual production of dry matter by cotton plants, and to make up for water lost by evaporation or by percolation through the soil, between 20 inches and 50 inches of water per acre are required. The actual amounts for a given location depend principally on rates of evaporation from the soil, evapotranspiration, and water percolation through the soils. The cotton plant is quite tolerant of water quality and will produce adequately on irrigation water from a relatively high mineral content. (Information taken from reference 7, page 164.)

Time to Maturity

Commercial cotton varieties are day-neutral. Cotton is, however, characterized as a chilling-sensitive plant. Injury to the plant occurs when it is subjected to temperatures below 15°C. In many areas in the world where cotton is grown, its chilling-sensitivity prescribes planting dates. Optimum growth occurs with day temperatures approximating 32-34° C. and night temperatures ranging from 21-27° C. It will, however, tolerate temperatures as high as 48-49° C., although pollen sterility begins to affect fruit-set when temperatures exceed about 45° C. during the flowering and fruiting season. A growing season of 150-200 days is required, the longer time being equated with maximum yields. (Information is from reference 7, page 164.)

Susceptibility to Diseases and Insects

Cotton is susceptible to seedling diseases on a worldwide basis. The severity is generally correlated with low temperature and high moisture regimes during germination, emergence, and early seedling growth. They can, in part, be controlled by seed protectants and systemic fungicides. Depending upon specific cotton growing areas, the other major cotton diseases are: *Verticillium* wilt, *Fusarium* wilt, bacterial blight, boll rots, and root rots. Plant resistance to some of these diseases has been found and incorprated into present-day varieties, particularly in the case of *Fusarium* wilt and bacterial blight. Cotton diseases continue to be a problem and, where they occur, are not generally controllable with fungicides.

A wide range of insects attack the cotton plant. The amount of damage produced by an individual insect species varies widely. In general, if an effective insect control program is employed, all of the insects can be controlled to an acceptable level.

Special Harvesting, Storage, and Processing Problems

Since cotton is already a major crop in Pakistan, no specific problems are envisaged for an increase in cotton acreage in this country. However, in order to increase yields substantially above the present level and to make efficient use of the products obtained, modern farming, ginning, and seed processing methods must be implemented.

WEST PAKISTAN ENVIRONMENT AND CLIMATIC ANALOGS 37/

With the exception of the Monsoon season in West Pakistan, many factors to be considered for cropproduction would be analogous to the Imperial Valley of California. Annual temperatures are high, with the summer temperatures being extremely high; growing seasons are almost year long; frost rarely occurs; and relative humidities are very high during certain seasons. The soil is alluvial and, for the most part, the water is relatively salt-free in both areas. However, with some of the soil salinity problems and the high water tables that exist in Pakistan, the natural purity of the water is reduced by pumping underground water into the irrigation systems for the purpose of lowering the water table. This water is very high in total salt content.

Still another area in the world that would be comparable is the Nile delta of lower Egypt; there both soil and climate are highly comparable. In both the Imperial and Nile regions, the production levels of cotton are quite high. In fact, in the Imperial Valley of California, three bales per acre were common until the advent of the pink bollworm in 1967. With tese two major cotton growing analogs as patterns, there is no reason why, technologically, cotton production in the Indus Plain of West Pakistan would not be comparable to the Imperial and Nile Valleys.

One concept that constantly arises in talking to the research scientist in West Pakistan is that of the "narrow ecological zone." While there is a higher temperature factor in the lower part of the country than in the central part, it is seriously questioned whether there is really that much difference in temperature, soil, water, and any other environmental factors which would make it necessary to have the many varieties that are being grown as specific adaptations to these so called "narrow ecological zones."

SOIL

A high percentage of the soil in the Indus Plain is alluvial in nature, but extensive travels in that country in 1966 showed that there were also loessal soils and that, in the land leveling that has occurred over a long period of time in many areas, there has been some mixture of both types. The cotton-producing areas to a great extent are on the alluvial soils, most of which have high clay fractions, typical of alluvial flood plains. There are all gradations from sandy to sandy-loam to heavy clay soils. Most of these soils can benefit by balanced fertilizer applications and, at this time, the use of inorganic fertilizers.

37/ This section draws heavily from reference 8, page 164.

WATER REGIME

Cotton is normally planted in late April to early June. Production could probably be increased by early planting, but at least 40 percent of cotton production follows wheat, and this means competition for land in the spring of the year. This also creates competition between the wheat and cotton production for available water during the latter part of the wheat growing season. Approximately 60 million acre feet of water, delivered in canals, is available for agricultural purposes annually. It should be pointed out that the distribution of this water is not stabilized because of high runoff during the summer snow melt and the Monsoon season. This often leads to excess water, even to the extent of extensive flooding of many of the agricultural areas during these seasons. In the later growing season, there may be a lack of enough water to meet the agricultural demands for extended periods. Recent developments of impoundment systems, particularly the Mangla Dam, will tend to stabilize this situation considerably.

Considerable improvement is needed in our understanding of the proper water requirements of the cotton plant for the optimum production. Even though many of the scientists of the Ministry of Agriculture are quite knowledgeable of water requirements for all plants, the lack of efficient extension services, and of farmers acceptance of information commonly leads to over-use of water during those periods of high availability. It is quite common to see 6 inches of water standing in fields 3 or 4 days after irrigation. Obviously, this leads to many problems.

WEATHER

The average rainfall in most of the producing areas of the country is something under 10 inches annually, most of this falling during the Monsoon season. Like most agricultural systems dependent on irrigation, the rain is apt to be more of a problem than a help in production practices.

The climate is quite hot during the summer season, and the temperatures are considerably higher during the winter than in most cotton producing countries of the world. Temperatures in May and June commonly reach 120° F. When temperatures reach 105° plus, successful fruiting becomes very low. This then leads to a long growing season in which a great majority of the fruit production occurs after August. It is possible that early planting dates, with the majority of the crop being matured prior to extremely high temperatures, would be beneficial. Relative humidity is apt to run high, particularly in the lower Sind region, as a result of prevailing winds off the Arabian Sea. Frost rarely occurs anywhere during the year in the cotton producing area.

DISEASES AND INSECTS

Diseases are not thought to be of significant importance in the production of cotton, However, there are seedling disease problems which give some difficulty. Insects, on the other hand, probably constitute one of the greatest production deterrents of any factor in the country. Most of the serious bollworm pests of cotton, including spotted bollworm, pink bollworm, corn earworm, and perhaps one other, are universal. Insects of lesser importance are the cotton leafroller, aphids, white fly, and spider mite. The Pakistani cotton research workers feel that the jassid (leaf hopper) is their most serious cotton pest. This is a questionable analysis since the jassid can be contolled fairly simply by a number of insecticides. The bollworms, however, pose an outstanding problem since they consume a high percentage of the production and, in observations made on several hundred fields toward the end of the season, all cotton bolls (fruit) examined contained bollworm damage. In addition, this creates quality problems in the end product, both seed and lint.

AVAILABILITY OF ADAPTED OR USEFUL GERM PLASM

The Pakistani cotton botanists (breeders) have made some efforts to obtain available germ plasm from other cotton growing countries of the world. However, most of the research workers are working in a rather narrow germ plasm base which offers them limited possibilities for improvement. One of the primary objectives of all botanists is to develop varieties with jassid resistance. They have been fairly successful in transferring the resistance from the so-called desi (*Gossypium arboreum*) types native to Asia but, unfortunately, the potential yield capacity is extremely low.

Some breeders' reports refer to germ plasm with oil content of the seed as high as 30 percent, but like breeders in other parts of the world, they tend to place primary emphasis on lint objectives and these materials have not been exploited.

IMPLICATIONS FOR YIELDS

The yield in lint cotton for West Pakistan was 272 pounds per acre in 1969-70, which would give a cottonseed yield of roughly 545 pounds per acre. With slight improvements of management practices, the importation of inherently high-yielding, American-type varieties,and adequate insect control, these yields could easily be doubled or even quadrupled in a relatively short time. Actually, this has already been demonstrated by American missionaries in one of the primary cotton growing areas.

IMPLICATION FOR MULTIPLE CROPPING SYSTEMS

This is a subject that perhaps more work has been done on than any other subject in agriculture in West Pakistan. The land is almost never idle. Wheat is the primary crop, with cotton being the primary cash crop, and there are all kinds of cropping schemes practiced and recommended for the country. In certain areas, rice is grown; in others, sugarcane. Winter rape and mustard is grown. One common practice is the growth of certain grass crops, particularly Bermuda grass, within the cotton fields to furnish forage for livestock.

STATUS OF RESEARCH

IN THE UNITED STATES

Production research on improving quality and quantity of oil in cottonseed has received some attention, but primary emphasis has been placed on lint. The successful effort to increase per acre lint yield in recent years has resulted in a concurrent increase in oil quantity per acre. Considerable effort has been made and is still underway to produce cotton varieties with glandless cottonseed. This would give some improvement to the oil and result in the removal of the gossypol-producing glands of the seed. The meal would then have potential uses for human nutrition.

Processing research on cottonseed has been conducted for many years. One of the more recent accomplishments has been the development of commercial-scale plants for the production of human-grade cottonseed flour. The process called the Liquid Cyclone Process (LCP) was developed by the Southern Utilization Research and Development Division, New Orleans, Louisiana, and is based on techniques developed by Dorr-Oliver, Inc. (Stamford, Connecticut). The process extracts the oil, removes the glands containing gossypol, and permits recovery of cottonseed protein as a human-grade 300 mesh flower over 65 percent protein (soybean flour = 50 percent) with about 0.02 percent free gossypol and 0.07 percent total gossypol. Cost of the product is about 8-10 cents per pound (soybean = 7 cents). It is expected to have a broader market capability than high protein flours presently available. One mill has been in operation for 2 years in Habli, India, financed by A.I.D. and another larger capacity mill is planned by the Plains Cooperative Oil Mill Co., Lubbock, Texas (See reference 6, page 164).

IN PAKISTAN

Little information is available on the status of research on cottonseed; however, some reports from botanists indicate certain

breeding selections with oil content as high as 30 percent. This is an extremely high percentage. This is no indication that commercial varieties vary much from the 20 percent figure, which is common to most known varieties.

With a national percentage of 13 for oil recovery, it would be reasonable to assume that oil extraction is done by highly inefficient techniques and crushing operations.

ELSEWHERE

Some of the research workers in the Cotton Research Corporation (British) have worked for a number of years in African cotton growing countries on improving oil content and decreasing the amount of fuzz (linters) on the seed. Similar objectives are now being pursued by C.S.I.R.O. in Australia.

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